

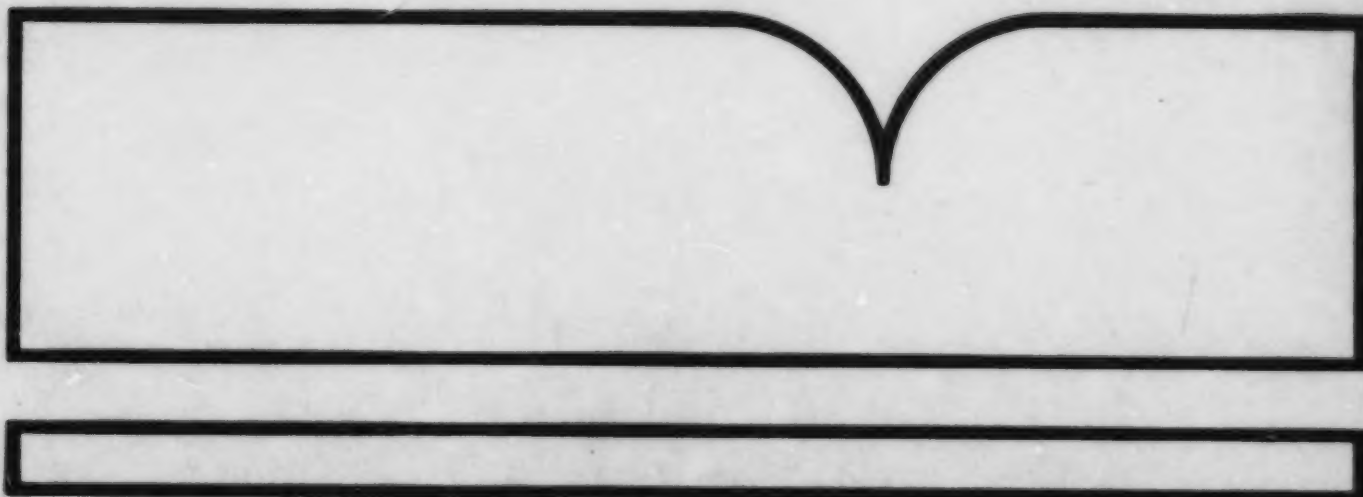
Handbook for Oil Spill Protection and
Cleanup Priorities

Rockwell International
Anaheim, CA

Prepared for

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and governmental concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components requires a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solving, and involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources; for the preservation and treatment of public drinking water supplies; and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and is a vital communications link between the researcher and the user community.

This report is a field manual for use by federally designated On-Scene Coordinators (OSC) to guide them in assessing priorities during all phases of an oil spill response by applying suitable decision-making processes. The report will be of interest to all those involved in oil spill prevention, control, and countermeasures.

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ABSTRACT

This manual was developed in an easily accessible yet extensive field format for use by federally designated on-scene coordinators (OSC) to guide them in assessing priorities during all phases of an oil spill response. The guidelines presented will enable the OSC to (1) determine pertinent facts about a particular oil discharge, (2) identify the resources and installations that may be affected, and (3) establish priorities for protecting and cleaning up these sensitive resources and installations.

Special attention is given to response activities such as (1) determining spill contamination potential, (2) rating area sensitivity to oil contamination, (3) establishing priorities for containment, protection, and cleanup, (4) deciding the best practical containment, protection, and cleanup methods, (5) assessing response effectiveness, and (6) deciding when to terminate cleanup efforts. Decision-making processes are outlined for all of the above response phases.

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SECTION 1

INTRODUCTION

Any oil discharged into marine or fresh water systems will inevitably affect both natural and man-made resources. These resources may only be important to and used by a small number of individuals, or they may be used and valued by a large portion of the local population. The rapidity and effectiveness of the oil spill response is of prime importance in averting potentially serious damage. Ideally, all potentially affected resources should be protected from damage. Usually, however, some priorities must be set to adequately use the available manpower and equipment for resource protection. Responsibility for determining priorities for both protection and cleanup lies with the designated on-scene coordinator (OSC) as mandated in the National Oil and Hazardous Substances Pollution Contingency Plan, Section 40 CFR 1510-36(a) (2) that states, "The On-Scene Coordinator shall determine ... potential impact on human health and welfare ... the resources and installations which may be affected and the priorities for protecting them."

This manual provides information and guidelines to aid the OSC in determining priorities. It provides methods by which field priorities can be determined under differing conditions. The general order in spill response is (1) to protect life and limb, (2) to minimize ecological impact, (3) to minimize socio-economic impacts, and (4) to minimize aesthetic impacts. This order is rational, but not fixed. Evaluations must be made at many points in this decision process and the overall response is the result of these evaluations. The methods in this manual are systematic and qualitatively satisfying, but they may not cover every possible situation. In view of this possibility, the OSC must exercise good judgment in applying these methods for determining field priorities.

The manual treats spill response actions chronologically, from arrival on the scene to implementation of protective containment and countermeasures, and cleanup and termination of effort. It does not directly address possible waste disposal or restoration priorities. It does not address specific technical operations since it assumes the user has a basic knowledge of oil spill mitigation methods and an understanding of coastal and inland environments. It also assumes that many required input data into the decision-making process can be found in existing oil spill contingency plans prepared by local or regional agencies.

USE OF THE MANUAL

The manual is divided into two parts. Part One (Section 2) is a self-sufficient field operations manual that delineates in a straightforward manner

the process of determining priorities. Part Two (Sections 3 through 11) consists of detailed technical references and relationships to be studied before applying the principles of priority determination. The experienced manual user will mainly utilize Part One, since he will already be cognizant of most of the background and support information contained in Part Two.

Sections 3 through 11 are organized to follow as closely as possible the normal sequence of events in an oil spill situation. The following paragraphs discuss in detail information requirements and implementation actions necessary for determination of priorities and the best practical methods for implementing them.

Section 3 - Spill Dynamics

The interaction of the oil spill with the environment that it enters determines the spill dynamics which influence contamination and damage potential. Spill factors include oil classification, oil discharge rate, and oil volume; methods are given for evaluating each factor. Environmental factors include wind (speed and direction), waves (height and period), currents (speed and direction), tides, and temperature.

Section 4 - Identification of Potentially Sensitive Areas

Areas particularly sensitive to oil contamination include natural ecosystems as well as recreational, residential, and industrial areas. The types and sources of application information are outlined in detail.

Section 5 - Sensitivity Rating of Areas

Once the affected or threatened areas have been identified, their relative sensitivity to oil contamination must be established. A numerical rating system is used based on four area values: (1) environmental, (2) economic, (3) social water use, and (4) aesthetic. These values are further refined by rating the importance of various outside considerations that usually arise in an oil spill situation.

Section 6 - Priority Determination

The order of priority of protective and cleanup efforts is based on such variables as: (1) total area sensitivity rating from the previous section, (2) order and degree of contamination, (3) vulnerability of affected area, and (4) wave energy of area. These are discussed and assigned numerical rankings for use in priority determination.

Section 7 - Best Practical Containment Methods

The first overall priority should be to contain the spill at the source. The best methods available for containment are discussed, and a decision guide is included.

Section 8 - Best Practical Protection Methods

Once the protection priorities have been established, the protection techniques must be ascertained. A decision guide and detailed discussion of dispersant usage are enclosed.

Section 9 - Best Practical Recovery and Removal Methods

Once the cleanup priorities have been established, methods of mitigating the spill must be ascertained. Involved in this decision are (1) best methods available in each area, (2) effectiveness of such methods, (3) environmental impacts of such methods, and (4) acceptability of natural cleanup. Each consideration is discussed in detail.

Section 10 - Implementation and Evaluation of Selected Actions

Actions should be implemented immediately after priorities have been established and available control methods are known. Since spill dynamics may change, constant reassessment and re-evaluation of the total spill response are necessary. If the response is not as effective as desired, some reordering of priorities or selected actions may be necessary. All these topics are discussed, and decision-making processes are outlined.

Section 11 - Termination of Effort

The decision to terminate cleanup efforts must take into account the benefits of continued cleanup from the aesthetic, environmental, and socio-economic standpoints in relation to the cost (manpower, equipment, and time) required for continued effort. All these factors are discussed in detail.

ASSUMPTIONS FOR THE USE OF THE MANUAL

Because it will be almost impossible to apply any one priority system to all diverse oil spill situations, some basic assumptions must be made. These are as follows:

- Many of the required inputs are found in existing oil spill contingency plans
- The process is only as valid as the information inputs
- The OSC must always use his best judgment in making and applying decisions when the system is inappropriate
- No system can replace the experience and knowledge of the OSC; therefore, the manual is only a tool and not a substitute for the OSC's judgment
- The OSC will be capable of deriving more benefit from the system each time it is used since he will become more familiar with the sensitivity rating system and the priority determination method

SECTION 2

FIELD MANUAL

This section is the self-contained Field Manual intended to aid the OSC in determining priorities with a minimum of reference material. It is a step-by-step process in the order of a spill response, with references to the support material in Part Two. Tables and figures are numbered consecutively in order of occurrence in Part Two, and their page location may be found in the Contents section. The decision process may be applied at one or more points in time during an oil spill response to ascertain protection and clean-up priorities as the action continues. Each step is fully outlined in Part Two and the user should be familiar with each step before applying this process. Appendix A is a complete example of the use of this manual in a hypothetical spill situation. Figure 1 is a Decision Flow Chart which contains all the steps, listed below:

Step A. Obtain spill factors (Section 3) from:

- Initial notification report
- On-site spiller's information
- Local public service personnel (i.e., police or fire departments)
- Aerial surveillance of spill site

Step B. Obtain environmental factors (Section 3) from:

- On-site spiller's information
- Local public service personnel
- Local public service personnel
- Aerial surveillance of spill site
- Local weather service offices
- Local citizens

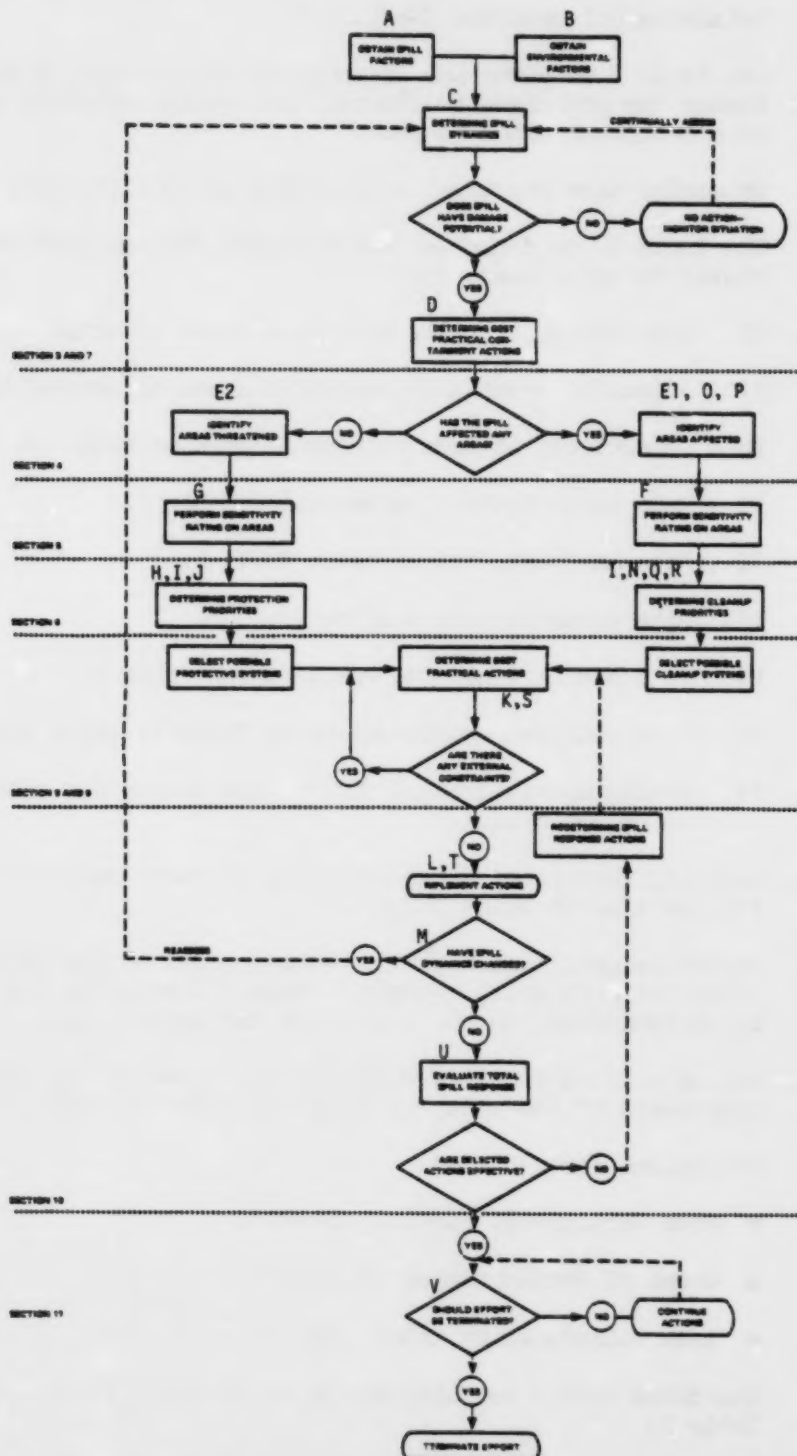


Figure 1. Decision flow chart for oil spill priorities.
(letters are steps in decision process)

Step C. Determine oil behavior (Section 3)

Use Table 2 to determine if environmental factors will aid or hinder the containment efforts. Use vector addition to determine resultant slick movement.

Step D. Determine best practical containment methods (Section 5).

Use Table 20 to determine which containment methods are best suited to spill situation.

Step E. E1. Identify potentially sensitive areas affected (Section 4).

E2. Identify potentially sensitive areas threatened (Section 4).

Step F. Rate sensitivity of each threatened area on Table 10.

F1. Rate environmental values using Table 5.

F2. Rate aesthetic values using Table 6.

F3. Rate economic values using Table 7.

F4. Rate social water use values using Table 8.

F5. Rate outside considerations on Table 11 using Table 9.

F6. Obtain modified total sensitivity rating for each area using Table 11.

Step G. Rank the threatened areas according to their relative sensitivity (Section 5) using Table 11.

Step H. Determine predicted order of contamination of the threatened areas based on spill dynamics. Number 1 would be the first to be contaminated, number 2 would be the second, etc.

Step I. Assign a value for area vulnerability based on the physical components of the area, by using the index in Table 12.

Step J. Sum values for:

- Area sensitivity rankings (Step G)
- Order of contamination (Step H)
- Area vulnerability index (Step I)

Use these values to determine protection priorities as shown in Table 13.

- Step K. Determine best practical protection methods for each area (Section 8). Use decision guide in Table 22.
- Step L. Implement protective actions according to priorities using best practical methods (Section 10).
- Step M. Reassess spill dynamics (Section 10). Use Table 31 to determine if changes in spill dynamics will affect spill response phases.
- Step N. Reorder or change protection priorities and implement actions to effectively reduce spill damage to sensitive areas.
- Step O. Determine potentially sensitive areas affected since the beginning of the spill (Section 4).
- Repeat Step G. Rate sensitivity of each affected area for all values aesthetic, environmental, economic, social, and outside considerations). Use Tables 5, 6, 7, 8, and 9, and the worksheet in Table 10 (see Step F). Rank areas according to sensitivity ratings using Table 11.
- Step P. Determine degree of contamination for each affected area. Use Table 14 to assign a rating to each area.
- Repeat Step I. Determine vulnerability index values for each affected area. Use Table 12 to assign a value to each area.
- Step Q. Determine a wave energy index value for each affected area (Section 6). Use Table 15 to assign a value.
- Step R. Sum values for:
- Area sensitivity rankings (Step G)
 - Degree of contamination (Step P)
 - Area vulnerability index (Step I)
 - Wave energy index (Step Q)
- Use these values to determine cleanup priorities as shown in Table 16.
- Step S. Determine best practical cleanup and recovery methods for each area (Section 9). Use the following reference tables:
- Table 25: Decision Guide for Water Cleanup Methods
 - Table 27: Decision Guide of Applicable Shoreline Cleanup and Recovery Techniques
 - Table 28: Impacts of Cleanup and Recovery Techniques

- Table 29: Criteria for Comparing Effectiveness of Cleanup Techniques

- Table 30: Effectiveness of Cleanup Techniques

Step T. Implement cleanup and recovery actions according to priorities using best practical methods (Section 10).

Step U. Evaluate overall spill response using the criteria in Table 32 (Section 10).

Step V. Decide if effort in each area should be continued or terminated (Section 11) by using Tables 33 and 34.

SECTION 3

SPILL DYNAMICS

INTRODUCTION

Oil spill dynamics refers to those factors that produce a change during an oil spill incident. These are (1) spill factors — those directly related to the spill, and (2) environmental factors — those directly related to the spill location. Knowledge of one of these factors alone would be inadequate in making a spill response.

Spill Factors

Spill factors related to the discharge (spill) itself. The input data include:

- Type of oil
- Type of discharge (sudden or continuous)
- Time of spill occurrence
- Quantity of oil discharged and estimated rate of flow if discharge is continuous

These inputs can be obtained from the initial report and field verification.

Environmental Factors

Environmental (site) factors include the actual conditions at the spill location. The input data for these factors include:

- Spill location
- Wind speed and direction
- Water current speed and direction
- Air and water temperatures
- Tide data
- Season (e.g., breeding season for mammals or birds, fishing season, etc.)

These data are available from initial reports and field verification.

These two sets of factors make up the data required to determine the spill dynamics. As changes occur in either set, the spill dynamics will change. This change may require a reordering of response priorities.

However, before a spill response is initiated, priority should be given to personnel safety. An evaluation of the potential hazards such as fire, explosion, BLEVE (boiling liquid - expanding vapor explosion), and injurious vapors should be considered before a response is made. This relies on the best judgment of the OSC and the monitoring capabilities at his disposal. This is particularly important during spills of free-flowing oils such as aviation gas, jet fuel, gasoline, kerosene, and the lighter fuels and crude oils.

SPILL FACTORS (STEP A)

The spill factors include those aspects of an incident that directly relate to the oil. These are:

Type of Oil

Unless a spill has just occurred, information about the type of oil will probably be inadequate. This is because weathering changes the oil. However, field personnel can observe the oil's behavior and determine the oil type. This behavior is related to the oil's chemical and physical properties. The rate at which oil spreads is influenced by its viscosity, surface tension, specific gravity (all temperature-dependent), and time.

The oil classifications presented in this manual have been developed from several sources. Defining oils as light, medium, or heavy is not appropriate for the field observer. Confusion may arise because these particular adjectives apply to specific types of oil such as heavy fuel oil or light crude oil. The manual's definitions apply to the oil's observable characteristics on water (Table 1). This approach has been taken for two reasons. First, by concentrating on physical properties of the spilled oil, initial actions can be taken even if the proper name of the oil is unknown. Second, response always requires time to implement countermeasures, and during any time lapse, a process known as weathering changes the oil. As an oil weathers, it changes both internally and in appearance. Thus, if oil were to be classified only by original chemical composition, or original oil properties, the classification would be inadequate to describe the weathered oil. These oil classifications are briefly described below and a decision chart for the identification of oil types is found in Figure 2.

Free-Flowing—

These oils contain volatile components which evaporate readily when the oil is released into the environment. Because of this, the ignition potential is high, and a fire or explosion hazard exists in the spill area. In addition, a personnel hazard may exist because of the vapors. These oils flow easily, spread rapidly, and penetrate porous substrates deeply. They usually appear transparent or slightly opaque and easily rinse off surfaces.

TABLE 1. OIL CLASSIFICATIONS

Observable Character	Specific Gravity [60°F (15°C)]*	API Gravity† (15°C)	(ASTM D-38 D-445) Viscosity [cS/60°F (15°C)]*	Oil-Water Tension‡ (dyne/cm)	Examples
Free-flowing oil	0.83-0.88	30 - >60	3-10	20	Gasoline, kerosene, gas oil, fuel oil #1, #2, very light crude oil or condensate
Viscous oil	0.90-0.94	15-30	100-300	20	Fuel oil #4, tar-low oil, #2 mineral oil, medium gravity crude oil
Semi-solid tar-like oil	0.94-0.97	< 15	500-2000	20	Fuel oil #5, #6, #10, tall oil, asphalt, heavy crude oil

* ASTM Standard for Test Oils (these ranges are typical)

† Fingas, M.F., et al., 1979

‡ Stewart, R.J., 1976. (These values are typical; actual spilled oil may have different values.)

Viscous—

These oils contain some volatile components but are less likely to create a fire hazard. They are usually opaque, form emulsions readily, have variable soil penetrability, and can be removed from surfaces by applying low-pressure water spray. These oils may feel waxy.

Semi-Solid Tar-Like—

These oils are opaque and spread slowly or form "tar balls." They have low substrate penetrating ability, feel sticky, and are difficult to remove from contaminated surfaces. Emulsions formed by these oils are very stable.

Type of Discharge

A discharge may be a sudden occurrence at which time all oil is released or it may be an occurrence during which the oil is released continuously over a period of time.

Time of Spill Occurrence—

During the time between the spill occurrence and the spill response, the oil slick location may move. If the time of the release is known, the location and quantity of the slick may be predicted.

Quantity of Oil Discharged—

The quantity of oil released will influence the amount of protection and cleanup equipment dispatched to the spill site. Volume definitions are those in the proposed revisions to the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR Part 1510).

<u>Discharge</u>	<u>Inland Waters</u>	<u>Coastal Waters</u>
Minor discharge	<1,000 gal (24 bbl)	<10,000 gal (240 bbl)
Medium discharge	1,000-10,000 gal	10,000-100,000 gal
Major discharge	>10,000 gal (240 bbl)	>100,000 gal (2,400 bbl)

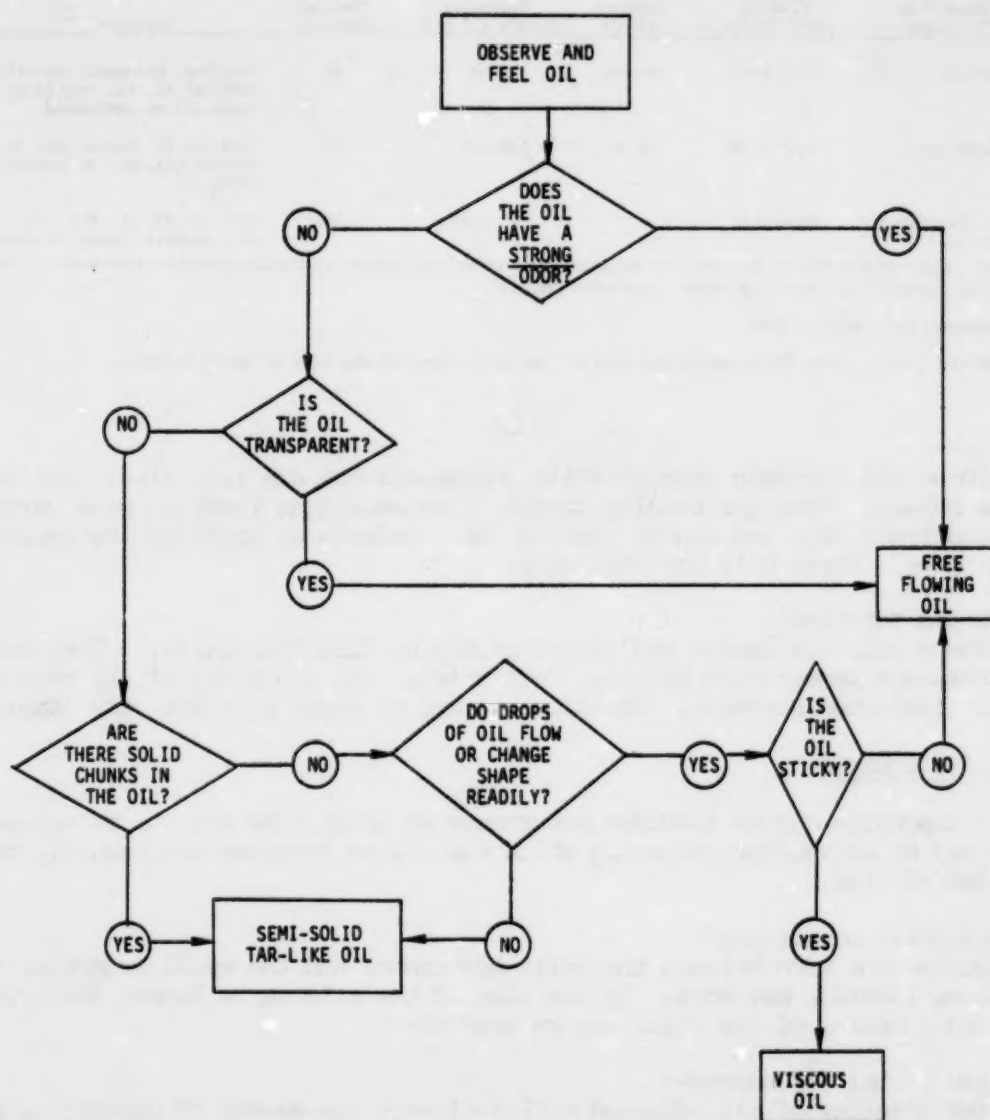


Figure 2. Decision chart for identification of oil type.

The terms used to describe an oil film, which is a slick thinner than 0.0001 inch, are given below (Council on Environmental Quality, 1979).

<u>Standard Term</u>	<u>Gallons of Oil Per Square Mile</u>	<u>Appearance</u>
Barely visible	25	Barely visible under most favorable light conditions
Silvery	50	Visible as a silvery sheen on surface water
Slightly colored	100	First trace of color may be observed
Brightly colored	200	Bright bands of color are visible
Dull	700	Colors begin to turn dull brown
Dark	1300	Colors turn a much darker brown

Note : Each 1-inch thickness of oil equals 5.6 gallons per square yard, or 17,000,000 gallons per square mile.

ENVIRONMENTAL FACTORS (STEP B)

The environmental factors include the conditions at the spill location. They are as follows:

Spill Location

Spill location is expressed in latitude and longitude and aids in locating the oil slick and oil source on a map.

Wind Speed and Direction

Wind contributes to oil slick motion. Wind speed is expressed in mph or knots; direction is expressed as a compass reading such as N, NW, or SE from which the wind is blowing.

Water Current Speed and Direction

The speed and direction of the current must be known to predict the location of a moving slick. Current is expressed in knots, cm/sec, or m/sec.

Air and Water Temperature

Both air and water temperatures will affect the weathering process and may alter the spill response efforts. Oil will behave differently in weather extremes. In cold weather, oil will spread less and maintain its chemical and physical properties; in hot weather, oil will spread quickly and volatilize its low-boiling components readily. Additionally, during temperature extremes,

allowances for equipment operation and personnel protection will need to be considered in the response effort.

Tide Data

In tidal areas such as embayments and large rivers, the tidal cycle can greatly influence the water current speed and direction, but in a predictable manner. Tides are extremely important in oil movement and countermeasure employment.

Season

The season in which the oil spill occurs may result in added sensitivity of a potentially threatened or affected area. For example, the oil spill may threaten a fishing reserve during the fishing season or a bird or mammal rookery during the breeding season.

OIL BEHAVIOR ON WATER

Three main processes occur when oil is released into the environment.

Oil-Spreading

Oil-spreading is the first process observed as oil is released into the environment. The spreading rate is a function of the oil's viscosity and surface tension. The volume of oil spilled affects the spreading rate during the initial stages of a spill.

On waters uninfluenced by wind or currents, oil will rapidly spread into a circular pattern. The maximum radius of this circle can be calculated using Fay's formula expressed as:

$$r_{(max)} = 293.7 (n)^{.375}$$

where

$$r_{(max)} = \text{final radius of the circular spill in feet}$$

$$n = \text{volume of oil spilled expressed in barrels} \\ \text{(42 gallons)}$$

However, if sufficient wave motion is present, water-in-oil emulsions occur which rapidly increase viscosity, reducing the spreading rate.

Oil Movement

The second observable process is the oil movement, which is mainly influenced by wind and current. If debris is present in excessive amounts, it will also affect the movement of oil. In the absence of current and debris, the oil will move in the direction of the wind at approximately 3.5 percent of the wind velocity. In the presence of wind and current, it is generally acceptable to add their effects vectorially. In addition, for spills moving long distances,

the Coriolis effect of the earth's rotation may move the slick slightly right of the wind direction in the Northern Hemisphere and slightly left of the wind direction in the Southern Hemisphere. Examples of the vector addition modified from those of Lissauer and Welsh are shown in Figure 3. This vector addition provides only an estimate of slick movement, which should not be considered absolute.

In coastal spills, the tidal currents will play a role in the oil behavior. Oil will move with the current and may contaminate new areas or render protective methods ineffective. Generally, oil does not readily adhere to wet surfaces. A spill on a shoreline at the flood current (as the water moves landward) will not penetrate the saturated surface as quickly or as deeply as oil on the ebb current (as the water moves seaward). On the ebb current, oil is carried onto drained or even dry surface and will tend to adhere and penetrate into the shoreline strata.

Weathering

The third process is weathering. Weathering is a natural process that alters the chemical and physical properties of the spilled oil. It begins as soon as the oil is released into the environment and proceeds at rates that vary according to the type of oil and environmental conditions. In general, these rates are highest during the first 4 to 12 hours after the release. The major weathering processes are evaporation, dissolution, oxidation, emulsification, and microbial degradation. Each is briefly described here. Additional information is available in the following references: Boesch, D., et al., 1974; Edison Water Quality Laboratory, 1971; and Fingas, M.F., et al., 1979.

Evaporation affects the release of the oil's low-boiling volatile components into the atmosphere at rates dependent upon the vapor pressure and the boiling points of each component.

Dissolution releases water-soluble oil components into the water below the oil surface. It occurs first in aromatic components of the lower molecular weight hydrocarbons, then in alkane components of the same boiling point. The emulsions produced can be either oil-in-water, which usually requires the aid of a surface-active agent, or water-in-oil, which forms naturally. It is the water-in-oil emulsion that forms the "chocolate mousse"; this is slow to degrade and hard to disperse.

In biodegradation, microorganisms use the hydrocarbon as a food source. During this process, the hydrocarbon is reduced to a simpler form by either aerobic organisms, those requiring free oxygen for survival, or anaerobic organisms, those requiring the absence of oxygen for survival. In either case, the oil is degraded by the organisms preferentially and sequentially attacking the normal alkanes, the branched alkanes, the cycloalkanes, and finally the aromatic components.

Regardless of the particular mode of weathering, the resultant oil is changed in appearance and behaves different from freshly spilled oil. As oil gets heavier (that is, its specific gravity exceeds that of water) by one of the processes mentioned above or by the adsorption of oil on particulate

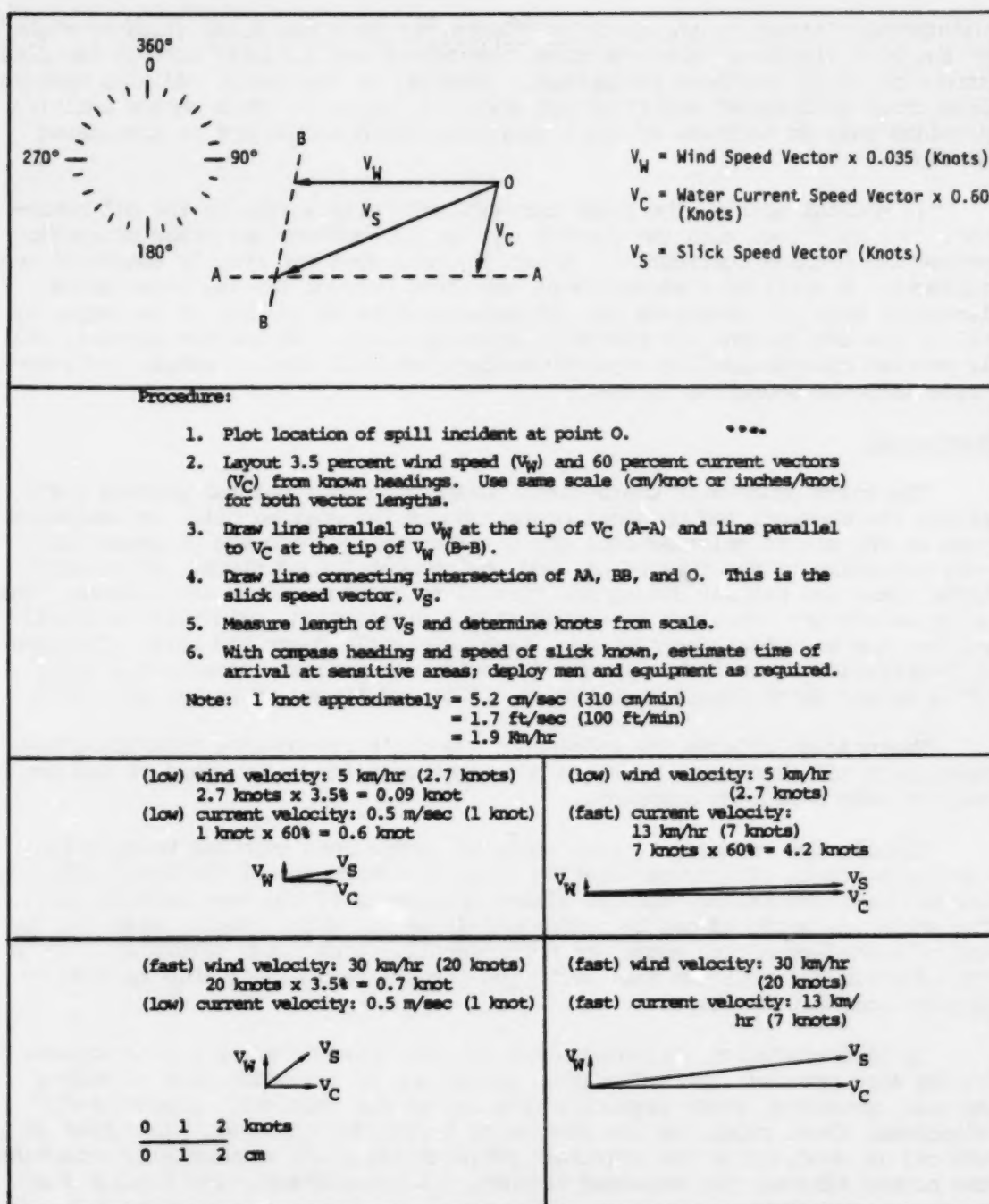


Figure 3. Prediction of slick movement with examples of vector addition.

material, it will sink. When oil sinks, it can contaminate the bottom of the water body or be acted upon by microorganisms. If microbial oxidation reduces the density of the oil, it might resurface and float again. This process can continue until the weathered oil residue disappears or reaches a land mass.

Each oil classification behaves differently under different water conditions. There are some conditions under which the spill will be aggravated. Conditions such as extremely hot weather with wave action and fast currents would result in a semi-solid, tar-like oil being emulsified or sunk. Table 2 indicates the behavior of oil under different conditions -- cold, moderate, and hot.

	<u>Cold</u>	<u>Moderate</u>	<u>Hot</u>
Air temperature	$\leq 4^{\circ}\text{C}$ ($\leq 40^{\circ}\text{F}$)	$> 4^{\circ}\text{--}32^{\circ}\text{C}$. ($> 40\text{--}90^{\circ}\text{F}$)	$> 32^{\circ}\text{C}$ ($> 90^{\circ}\text{F}$)
Water temperature	$\leq 0^{\circ}\text{C}$ ($\leq 32^{\circ}\text{F}$)	$> 0^{\circ}\text{--}30^{\circ}\text{C}$ ($32\text{--}85^{\circ}\text{F}$)	$> 30^{\circ}\text{C}$ ($> 85^{\circ}\text{F}$)

In Table 2, those conditions that would tend to reduce oil spreading and emulsion formulation and aid in spill response efforts are indicated by a +. Those conditions that would tend to aggravate the response efforts by allowing the oil to move rapidly, spread widely, and form emulsions are indicated by a -. Those conditions that do not seem to affect oil behavior at all are indicated by 0.

DETERMINING OIL BEHAVIOR (STEP C)

There are many conceptual bases for predicting the location of an oil slick by use of a computer model that are beyond the scope of this manual. These are especially valuable in determining both short- and long-term forecasts for both the horizontal and vertical dispersion of the oil. However, it takes time to gather and enter input data required for an accurate computer model. Until this is completed, the vector addition technique of Lissauer and Welsh should be employed. For those interested in computer models, Appendix B provides a list of pertinent references.

TABLE 2. BEHAVIOR OF OIL AS RELATED TO ENVIRONMENTAL CONDITIONS

General Category of Water	Free Flowing Oil			Viscous Oil			Semi-Solid Tar-Like Oil		
	Moderate ^a Clean Water	Cold ^a	Hot ^a	Moderate Clean Water	Debris	Hot	Moderate Clean Water	Cold ^a	Hot
General Category of Water									
A. Rivers and Protected Waters									
1. Shallow Water 0-0.5 m (0-1.5 ft)									
a. low waves	+	+	-	+	+	-	0	+	-
low/moderate current	-	+	-	-	+	-	0	0	-
fast current									
2. Moderately deep water 0.5-1.5 m (1.5-5 ft)									
a. low waves	+	+	-	+	+	-	0	+	0
low/moderate current	-	0	-	-	+	-	0	0	-
fast current									
b. moderate waves	-	+	-	0	0	-	-	+	-
low/moderate current	-	-	-	-	-	-	-	0	-
fast current									
3. Deep water >1.5 m (5 ft)									
a. low waves	+	+	-	0	0	-	0	+	0
low/moderate current	-	+	-	-	0	-	0	0	-
fast current									
b. moderate waves	-	+	-	0	0	-	-	+	0
low/moderate current	-	-	-	-	0	-	-	0	-
fast current									
B. Open Water - Inland or Ocean									
1. Very deep water >6 m (20 ft)	0	-	-	0	0	-	-	+	-
a. high waves									
low/moderate current									

Wave height: low 0-0.3 m (0-1 foot)
moderate 0.3-1 m (1-3 feet)
high 1-2.5 m (3-8 feet)

Current: low/moderate <0.8 m/sec (<1.5 knots)
fast >0.8 m/sec (>1.5 knots)

^a air temperature
moderate >4-12°C (>40-90°F)
cold <4°C (<40°F)
hot >32°C (>90°F)
water temperature
moderate >0-30°C (32-85°F)
cold <0°C (<32°F)
hot >30°C (>85°F)

+ Environmental conditions will help hinder oil behavior (aid spill countermeasure)

0 Neutral

- Environmental conditions will aggravate oil behavior (hinder spill countermeasure)

Terms modified from ASTM proposed standard description of environmental conditions relevant to spill control systems for use on water (3/11/78).

SECTION 4

IDENTIFICATION OF POTENTIALLY SENSITIVE AREAS (STEP E)

INTRODUCTION

Before establishing priorities, accurate information about the locations and characteristics of both affected and threatened areas must be obtained as quickly as possible. Ideally, most general information will be available from existing or interim local, state, or regional oil spill contingency plans. In the event that contingency plans are either incomplete or unavailable, alternative information sources exist, each of which can provide the OSC with useful information. A list of these sources is presented in Appendix F along with the type of data available. Another major source of information is the OSC's familiarity with the geographical spill area. It is assumed that the OSC has or can obtain detailed topographic maps of the entire area potentially vulnerable to the spill. The terms below should be used to locate and identify these sensitive areas. This section examines site characteristics, and Section 5 rates their sensitivity based on environmental (ecological), aesthetic, economic, or social values.

Important potentially sensitive areas are divided into six general categories and are illustrated in Figure 4. These are as follows:

- resource management areas
- consumptive water use areas
- recreational use areas
- commercial use areas
- industrial use areas
- unused natural ecosystems

RESOURCE MANAGEMENT AREAS

These are essentially natural areas but are presently managed by man for maximum biomass production, wildlife conservation or preservation, or other important resource uses. Included are areas used for:

- fish nurseries
- shellfish aquaculture

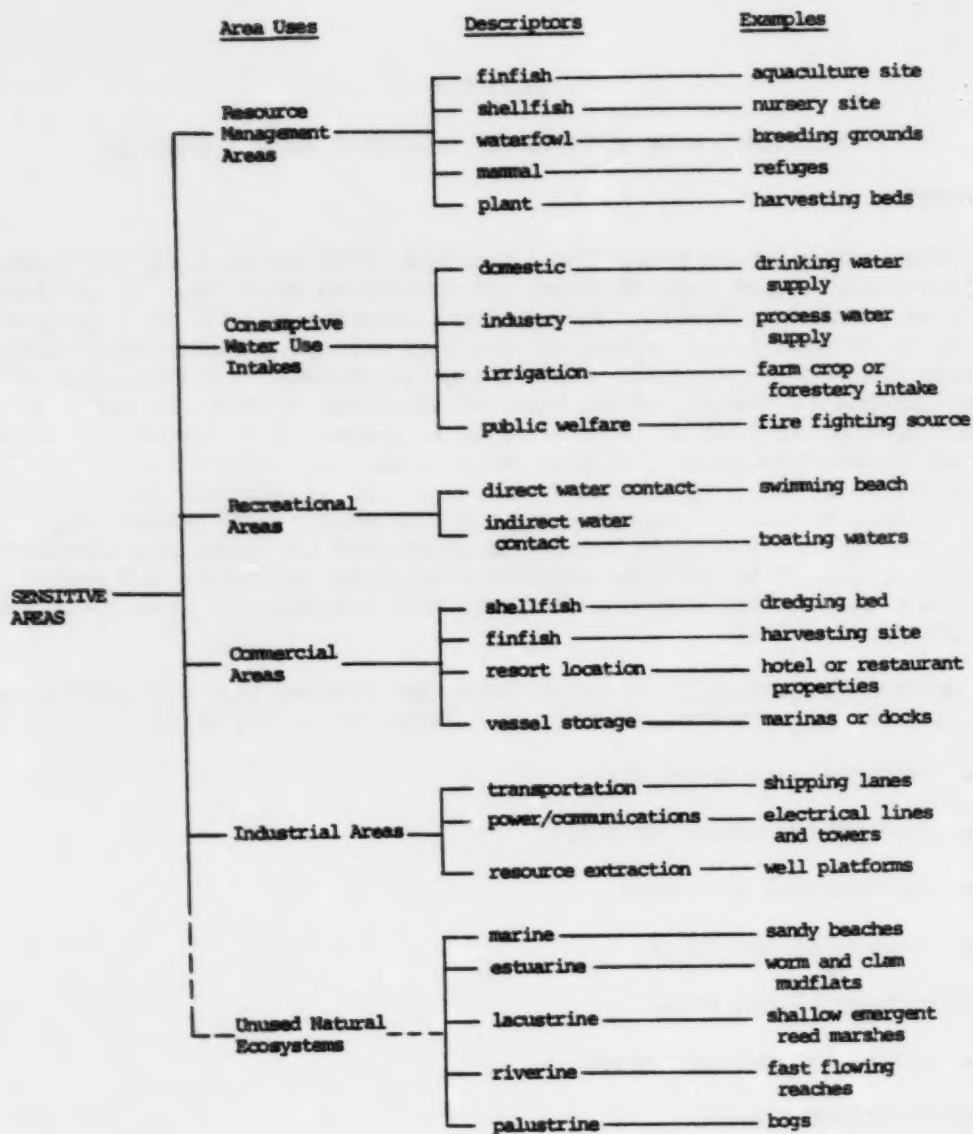


Figure 4. Important potentially sensitive areas.

- wildlife refuge
- wildlife breeding grounds
- nesting or roosting sites
- migration stopovers
- mammal protection
- endangered species habitat
- algae culture
- beach stabilization
- archaeological study
- tribal fishing areas
- historical monuments

CONSUMPTIVE WATER USE AREAS

These areas supply man with water on a consumptive basis (that is, there is a net withdrawal of water). They contain structures such as water intake pipes, dams, or channels for water transport or storage. Included are the following:

- domestic water supply
- industrial process water supply
- industrial cooling water supply
- farm crop irrigation
- forestry irrigation
- landscape irrigation
- fire-fighting

RECREATIONAL USE AREAS

These areas provide recreational opportunities either through direct or indirect contact with water. Structures such as boat ramps, docks, piers, house supports, water skis, surfboards, navigational markers, fishing equipment and boats are found within them. Included in this category are the following:

- direct contact areas
 - swimming
 - scuba diving
 - snorkeling
 - water skiing
 - surfing

- indirect contact areas

- motor boating
- sailing
- sport fishing
- canoeing or rafting
- waterfowl hunting
- camping

COMMERCIAL USE AREAS

These areas consist of commercial finfish and shellfish harvest areas that are not managed by man. Also included are areas that attract tourists because of the proximity of a body of water. Included are the following:

- sessile and mobile shellfish harvesting
- trawling
- long-lining
- netting or seining
- beach-front hotel or restaurant properties
- marinas and boat harbors
- beaches adjacent to roads or highways

INDUSTRIAL USE AREAS

Industrial use areas are usually for nonconsumptive water users, and many are extremely large and cannot be classified as a single entity. Included in these areas are such structures as well platforms, electrical towers, submerged cables and pipelines, bridge foundations, vessels, locks, buoys, seawalls, channel bulkheads, jetties, storm sewer systems, flow monitoring equipment, surface runoff systems, and various underwater structures. Some area uses include the following:

- resource extraction
- communications
- navigational lanes/transportation
- logging
- waste disposal
- power generation
- flood control impoundment

UNUSED NATURAL ECOSYSTEMS

These areas are not directly used by man, but have important scenic or ecological significance. They are distinct areas because of their size, geomorphology, or location, and each must be rated separately as to its particular

sensitivity to oil contamination. Included are areas located in marine, estuarine, lacustrine (lake), riverine (river), and palustrine (marsh) aquatic environments. They are listed in Table 3.

DETERMINATION OF AFFECTED AREAS (STEP E1)

The first problem to be addressed by the OSC after the spill has been stopped or contained is to determine what areas have been affected and what areas are threatened and need protection. Once the facts are established, the OSC can begin the sensitivity rating (Section 5). Contaminated areas are identified primarily by direct observation of one or more of the following: (1) black discoloration of the waterline; (2) so-called "chocolate mousse" and tar balls; (3) a shiny, oily sheen on the water surface; or (4) pockets of oil accumulation.

Several methods of observation (for example, land surveillance, local reports) of an area are available, but aerial surveillance is the most effective. Surveillance is generally made from small planes, and police, Coast Guard, or television station helicopters. The local population also furnishes reports of site contaminations. Reports of fouled drinking water, oiled boats and ships, and dead wildlife all indicate that an area has been affected. In some cases local officials, such as park and wildlife rangers, may be dispatched to a reported area to gather a more detailed account of the spill damage. The location of areas already affected can aid in the determination of potential spill damage, spill movement, and the location of potentially threatened areas.

DETERMINATION OF THREATENED AREAS (STEP E2)

After contaminated areas have been located, efforts must be directed to identifying all possible threatened areas. Four factors are involved:

1. Proximity of spill site
2. Alignment with predicted spill trajectory (as determined in Section 3)
3. Continued spillage moving toward area (for example, leaking barge adrift)
4. Movement of sensitive area component into spill site (for example, fisheries stock or waterfowl migration)

Threatened areas must be rated as to their sensitivity and, in turn, prioritized for spill control efforts by the OSC. Generally, highest priority should be given to protection of threatened sensitive areas. Cleanup of contaminated areas may have to wait until protection methods have been deployed, unless all sensitive areas are already contaminated and no others are threatened.

TABLE 3. UNUSED NATURAL ECOSYSTEMS POTENTIALLY
SENSITIVE TO OIL CONTAMINATION

Marine (salinity $\geq 3\%$)	• open waters • rocky shorelines • sandy beaches or bars • coral reefs • vascular/algal submergent beds • mud flats • tidal pools • succulent (shrub) salt marshes • reed salt marshes • red mangrove swamps • black mangrove swamps
Estuarine (semi-enclosed, land influence, fresh water diluted, salinity $< 3\%$)	• open waters • rocky shorelines • sandy shorelines • channels • oyster reefs • mud flats • vascular/algal submergent beds
Lacustrine (inland standing fresh water, large)	• open waters • seasonally flooded basins or flats • shallow emergent reed marshes • deep wooded swamps • sandy shorelines • rocky shorelines
Riverine (inland flowing fresh water)	• intermittent drainage tributary • fast flow reaches (high gradient) - riffles - pools - rocky shorelines - sandy shorelines • slow moving reaches (low gradient) - shallow reed marshes - deep wooded swamps - rocky shorelines - sandy shorelines - mud flats - open waters • tidal reaches - shrub swamps - deep wooded swamps - shallow reed marshes - rocky shorelines - sandy shorelines - mud flats - open waters
Palustrine (isolated fresh water, small and shallow, non-tidal and standing)	• bogs • ponds • reed marshes • deep wooded swamps • spring seeps

SECTION 5

SENSITIVITY RATING OF AREAS (STEP F)

INTRODUCTION

The overall sensitivity of an area to oil contamination is based on four complex interrelated factors: (1) environmental (or ecological) values, (2) aesthetic values, (3) economic values, and (4) social water use values. All areas will exhibit these values to varying degrees, and this sensitivity rating is based on the variation. When different relative degrees of each value are determined, the areas in question can be rated from most sensitive (least tolerant) to least sensitive (most tolerant). This rating system serves as the basis for priority determination and is therefore extremely important.

Some values are interrelated in such a way that a high sensitivity rating in one may be a factor in determining the rating in another. For example, an area that ranks high in ecological value may also rank high in economic value if the rating is based on biomass harvesting (for example, fisheries). Values, however, must be rated independently to obtain the accuracy needed for priority determination. This is because the economic value, in the example above, may not be realized if the fisheries' resource is not being harvested at the time of the spill.

This sensitivity rating system should be applied to all of the areas identified in Section 4. If the OSC is familiar with the rating system and has read the supporting reference material, he should be able to rate the areas in question relatively quickly and without use of this support document. However, if the OSC has not been exposed to the rating system or if time is extremely limited, he may elect to proceed to the preliminary screening technique in Section 6 -- Priority Determination. The user is discouraged from this course in all but the most extreme situations because it bypasses most of the OSC's judgment and is applied in a generalized manner based upon many assumptions.

This sensitivity rating system is applied to both threatened areas and affected areas because (1) their vulnerability to oil contamination is the same, and (2) the rating is based on area characteristics before the spill. The area values are divided into 16 categories as follows:

- environmental values
 - water quality degradation
 - biological productivity
 - ecological significance
 - unique habitat uses
 - ecological vulnerability

- aesthetic values
 - scenic quality
 - visual impact
 - local appreciation
- economic values
 - income or use reduction
 - natural resource damage
 - replacement and restoration costs
- social water use values
 - purpose of use
 - effect of oil on use
 - degree of direct contact
 - amount of use
 - treatment present before use of water

Even though the ratings for these area values are based on before-the-spill conditions, most of the ratings are dependent upon the amount and type of oil spilled. This relationship is found in the matrix in Table 4.

SENSITIVITY RATING OF AREAS (STEP F)

Environmental Values (Step F1)

Environmental values are based on the importance of natural ecosystems. An oil spill can produce drastic short-term effects and/or subtle long-term effects upon the ecology of an area. Because water systems exposed to chronic or frequent petroleum pollution will not exhibit the same sensitivities as an unspoiled area, environmental sensitivities are based upon the conditions of the potentially affected area before the spill.

Environmental values are extremely complex because of the interactions of an ecosystem's physical, chemical, and biological components as well as the highly variable interrelationships among populations within the area. Inputs to the sensitivity rating can be determined relatively quickly through visual reconnaissance and private and governmental sources. Some inputs are as follows:

- baseline water quality data
- baseline biological data
- topographic and hydrographic shoreline data
- season of the year
- sediment structure and composition data
- productivity of area for fisheries or shellfish harvest
- presence of endangered species and rare or threatened species

- use of area for scientific research
- diversity of habitats (for example, amount of mud flats, salt marshes, etc., within an area)
- presence of large mammals (for example, whales or sea lions)
- public and political concern for wildlife
- presence of legally mandated protection areas (for example, waterfowl sanctuaries and refuges)
- presence of aquaculture sites
- presence of area used for harvesting seaweed (for example, kelp beds)
- presence of stabilizing vegetation

The OSC should collect as much data as possible within time constraints and apply it to the following environmental values:

- water quality degradation
- biological productivity
- ecological significance
- unique habitat uses
- ecological vulnerability

Table 5 presents a matrix of environmental values.

Water Quality Degradation Guidelines--

This value rates the reduction of water quality from oil contamination, both chemical and physical, and the resulting stress upon organisms in the aqueous environment. The rating depends upon the water quality of an area before the spill since it is assumed that the most sensitive organisms would inhabit the area with the highest water quality.

- Low (1): An area that has poor water quality, rendering it unfit for any use because of siltation, organic wastes, or toxic pollution.
Example: grossly polluted lake.
- Moderate (2): An area that has fair or average water quality.
Example: urban river.
- High (3): An area that has good water quality or meets ambient water standards. Example: man-made reservoir.
- Extreme (4): An area that has excellent water quality or meets drinking water standards. Examples: mountainous trout stream.

Biological Productivity Guidelines--

The number and types of organisms that inhabit an area relate to the productivity and determine the severity of the biological toxicity by oil pollution. Both the density (number of organisms, all species, per area) and the diversity (number of species per area) are important in assigning a rating to

TABLE 5. ENVIRONMENTAL VALUES

	Increasing Sensitivity			
	low 1	moderate 2	high 3	extreme 4
WATER QUALITY DEGRADATION	Poor water quality before the spill so that it is unfit for any use.	Fair or average water quality before the spill.	Good water quality before the spill on the level of ambient water quality standards.	Excellent water quality before the spill on the level of drinking water quality standards.
BIOLOGICAL PRODUCTIVITY	Few species with low productivity.	Small populations of significant organisms but with low productivity.	Large populations of significant organisms with moderate seasonal productivity.	High productivity with high densities and diversity of significant organisms.
BIOLOGICAL SIGNIFICANCE	No food chain importance; used only for resting.	Little food chain importance; used for intermittent feeding.	Moderate food chain importance; used for breeding purposes.	Great food chain importance.
UNIQUE HABITAT USES	No unique uses or endangered species.	Unknown unique uses and rare endangered species sightings.	Some unique uses and frequent endangered species use.	Endangered or threatened species habitat.
BIOLOGICAL VULNERABILITY	No physical habitat modification possible; contains tolerant organisms.	Slight but reversible habitat modification possible; contains moderately tolerant organisms.	Severe but reversible habitat modification possible contains moderately sensitive organisms.	Long-term severe habitat modification would occur; contains highly sensitive organisms.

an area. The assumption is made that the denser or more diverse the organisms are, the more sensitive the area is. A highly productive habitat is also usually the source for repopulation of the surrounding areas. If such an area is disrupted by oil contamination, a disproportionate part of the region's populations could be affected.

Significant biota to consider are (1) water fowl (including shorebirds, diving birds, and swimming and surface feeding birds); (2) shellfish (clams, oysters, scallops, crabs, lobsters, and shrimp); (3) finfish (marine, freshwater, and anadromous); (4) marine mammals (sea otters, whales, seals, and sea lions); (5) terrestrial mammals (land otters, beavers, bears, muskrats, etc.); and (6) aquatic plants (emergent, floating-leaved, submersed, free-floating).

Guidelines for sensitivity Ratings:

- Low (1): An area containing only a few species that may be abundant but exhibiting low productivity. Example: rocky barren shorelines.
- Moderate (2): An area containing small populations of significant organisms but exhibiting low productivity. Example: sand beach.
- High (3): An area containing large populations of significant organisms but only moderate productive on a seasonal basis. Example: seal rookeries.
- Extreme (4): An area exhibiting high productivity with high densities and diversity of significant organisms. Example: coral reefs.

Ecological Significance Guidelines--

The reason significant organisms use a particular habitat is extremely important since it indicates the degree of potential contact with the oil. It also directly relates to the duration of use by the organisms. If an area has particular food chain importance, either ecological or human, its disruption will affect not only area inhabitants but outside food chain consumers as well. Any area where the destruction or disruption of juvenile forms or reproduction cycles occurs is considered highly sensitive. This criterion is extremely dependent upon seasonal variation, i.e., a tidal mud flat in winter will not be as sensitive as in spring or summer since birds will not be feeding on it.

Guidelines for Sensitivity Ratings:

- Low (1): Organisms use the area only for resting or other intermittent reasons and it has no direct food chain importance. Example: tidal sand bar.
- Moderate (2): Organisms use the area for intermittent feeding or seasonal habitation and it has little direct food chain importance. Example: tidal mud flats.
- High (3): Organisms use the area for breeding purposes or inhabit it on an annual basis and it has moderate food chain importance. Example: waterfowl rookeries.

- Extreme (4): Organisms use the area to complete their life cycles because it has great food chain importance. Example: coral reefs.

Unique Habitat Uses Guidelines--

An area where endangered or threatened species inhabit, feed, or breed is more sensitive than an area where the populations of significant organisms are found over a wide range and in great abundance with good repopulation potential. Also, an area may be used for a unique purpose by certain significant organisms such as haul-out locations for pinnipeds (seals, sea lions, and walruses) or waterfowl roosts.

Guidelines for Sensitivity Ratings:

- Low (1): An area that supports populations that exhibit an extremely wide range (i.e., ubiquitous), with no endangered or threatened species or unique uses present. Example: open ocean.
- Moderate (2): An area that supports populations that exhibit a wide range but in a clumped distribution, with rare sightings of endangered or threatened species and unknown unique uses present. Example: tidal river.
- High (3): An area that supports populations that exhibit narrow ranges with clumped distribution or with endangered or threatened species reported frequently and some unique use occurs. Example: seal rookeries.
- Extreme (4): An area that supports populations that exhibit an extremely narrow range, i.e., contains endangered or threatened species habitats. Example: endangered species habitat.

Ecological Vulnerability Guidelines--

This value reflects the adverse physical modification to habitats that may occur to an area from oil pollution. Habitat modification can happen through (1) incorporation of oil into sediments, (2) coating of rock or sand substrates, and (3) damage to protective shelter components (i.e., marsh grass). This value depends greatly upon the spill factors (e.g., volume and oil type) and significant organisms present.

All organisms do not exhibit the same response to oil pollution. There are varying degrees of susceptibility that generally can be classified into different sensitivities. This classification assumes all organisms within a significant group exhibit the same responses regardless of species or fitness of the individuals. This classification is only provided as a guideline and is not absolute.

Guidelines for Sensitivity Ratings:

- Low (1): An area that contains no physical components that would be adversely impacted so as to modify the habitats and contains:
 - gastropods (snails)
 - shorebirds (sandpipers, plovers, terns)
 - phytoplankton (algae, diatoms)

- Moderate (2): An area that would undergo slight and reversible habitat modification or contains:
 - finfish (marine, freshwater, anadromous)
 - bilvalves (oysters, clams, scallops, mussels)
 - cetaceans (whales, dolphins, porpoises)
 - zooplankton (copepods)
 - perennial plants with tap roots such as cordgrass (Spartina), reeds (Phragmites), spatter-docks (Nuphar), arrowheads (Sagittaria), cattails (Typha), and rushes (Juncas)
 - terrestrial mammals (land otters, beavers, bears, muskrats, foxes)
- High (3): An area that would undergo severe but reversible habitat modification or contains:
 - crustaceans (crabs, lobsters, shrimp, crayfish, barnacles)
 - invertebrates (worms, sponges, insects, starfish)
 - swimming and surface-feeding waterfowl (loons, grebes, ducks, geese)
 - seals, sea lions, and manatees
 - perennial plants without tap roots, such as buttonbush (Cephalanthus) and pickerelweeds (Pontedericia)
- Extreme (4): An area that would undergo long-term severe habitat modification or contains:
 - juvenile and larval forms of all animal species
 - seedlings of all plant species
 - diving ducks (scoters, eiders, long-tailed ducks)
 - sea otters
 - auks (murres, guillemots, puffins, razorbills)
 - shallow-rooted plants (annuals)

Aesthetic Values (Step F2)

Aesthetically pleasing waters add to the quality of life by enhancing the visual scene wherever they appear. Aesthetic values are highly site-specific and often subjective, thus making the development of general guidelines difficult.

Through visual reconnaissance and/or local citizen interviews, inputs into the sensitivity rating can be obtained and will include:

- general topographic and hydrographic patterns of the surrounding area
- abundance and uses of water system present
- abundance and uses of surrounding land areas
- degree of urbanization present
- wilderness and unique features present
- season of the year and degree of area use
- local citizen opinions and desire to preserve the area

The OSC must weigh all these considerations and apply them to the three aesthetic values:

- scenic quality of the area
- visual impact of oil in the area
- local appreciation of the area

In determining these criteria the OSC must depend heavily upon his prior experience and professional judgment to accurately assess an area's aesthetic sensitivity. Table 6 presents a matrix of aesthetic values.

Scenic Quality Guidelines--

This value is extremely subjective except in the most obvious situations. It relates the visual quality of an area and perceived worth by the general public.

- Low (1): An area with extremely low visual appeal or visual degradation, such as visibly polluted waters or disturbed landforms. Example: industrialized urban river.
- Moderate (2): An area with low visual appeal or where only man-made structures prevail (that is, no natural features). Example: channelized stream.
- High (3): An area with typical or average visual appeal such as plain or typical natural features. Example: rural man-made lake.
- Extreme (4): An area with unique natural features, beautiful vistas, or wilderness qualities. Example: wildlife preserve pond.

Visual Impact Guidelines--

This value refers to the potential reduction of aesthetic quality and its impact upon personal visual experiences by oil contamination. The visual impact of an oil slick directly relates the relative use of the area and the observer's ability to notice oil in the area.

- Low (1): An area where oil would be isolated and not seen by the general public. Example: isolated dense wetland.
- Moderate (2): An area where oil would be rarely noticed by the general public either because of its relative isolation or because of low visibility of the oil. Example: open harbor waters.
- High (3): An area where oil would be noticed by the general public. Example: recreational lake.
- Extreme (4): An area where oil would be extremely obvious to the general public. Example: resort beach.

Local Appreciation Guidelines--

This value is extremely site-specific and may be difficult to assess, since it includes local appreciation and aspiration for the area. It also

TABLE 6. AESTHETIC VALUES

	Increasing Sensitivity →			
	low 1	moderate 2	high 3	extreme 4
SCENIC QUALITY	Visual degradation such as polluted waters or disturbed landforms.	Low visual appeal associated with manmade features.	Moderate appeal quality associated with plain or typical natural features.	High visual appeal associated with unique or outstanding natural features.
VISUAL IMPACT	Oil isolated and not usually seen.	Oil rarely visible because of limited access.	Oil frequently visible because of moderate area use.	Oil highly visible because of extensive area use.
LOCAL APPRECIATION	No local appreciation or concern for scenic quality.	Individual appreciation or concern only.	Some local group appreciation or concern.	Strong local appreciation or concern with pressure to protect areas.

considers any historic sites, amount of site use, site access to water, and surrounding land uses of the area.

- Low (1): An area that generates no local appreciation or concern for its scenic qualities. Example: local land disposal site.
- Moderate (2): An area that generates only individual concern or appreciation for its scenic qualities. Example: private isolated waterfront property.
- High (3): An area that generates local group appreciation or concern for its scenic qualities. Example: residential developed ocean property.
- Extreme (4): An area that generates strong local group and/or individual appreciation or concern for its scenic qualities. Example: nature area with historic sites present.

Economic Values (Step F3)

Damage to an area that disrupts the economic balance is highly localized, and the primary victims are typically residents, tourists, and those who depend upon water for their income. Evaluating potentially damaged resources can be time-consuming, but if the OSC understands them he will be able to apply some of the techniques. Some methods, which are usually used for after-the-spill damage assessments, are as follows:

- Public perception of resource value — This is usually accomplished by direct interviews with local residents to determine the perceived importance of the resources within an area. This is similar to the average market value of a resource.
- Non-market value of resource -- This is determined by the value of non-market goods and services that can be inferred from an analysis of market transactions. For example, the value of a public beach may be inferred from the rental rates for private beaches in the same geographical area.
- Replacement costs -- These are costs of replacing a structure or restoring an area, even though an area may not be restored because of more important priorities.

Possible inputs are:

- type and number of persons dependent upon the area for their livelihood
- daily income of these persons
- degree of support services for these persons
- length of time resource would be unusable
- type and amount of area use that would be decreased

- planned future uses for the area
- total economic impact on overall area

The OSC must weigh all these considerations and apply them to the three economic values: (1) income or use reduction, (2) natural resource damage, and (3) replacement or restoration costs. Table 7 presents a matrix of economic values.

Income or Use Reduction Guidelines--

This value considers the total loss or reduction of either direct income or area use by oil contamination.

- Low (1): An area that would exhibit no loss or reduction of income or use resulting from oil contamination. Example: open ocean.
- Moderate (2): An area that would exhibit a slight loss or reduction of income or use because of oil contamination. Example: private fishing pond.
- High (3): An area that would exhibit a moderate total loss or reduction of income or use because of oil contamination. Example: recreational lake.
- Extreme (4): An area that would exhibit high total loss or reduction of income or use as a result of oil contamination. Example: resort beach.

Natural Resource Damage Guidelines--

This value is closely related to income or use reduction, but considers the long-term damage to renewable and non-renewable resources by oil contamination. Any resource or reserve that is currently being used or may be used in the future should be considered. Both the importance of the resource and the magnitude of the possible damage must be considered to rate the sensitive area taking into account both short-term depletion and long-term degradation (for example, tainting of seafood).

- Low (1): An area that exhibits no resource damage resulting from oil contamination. Example: arctic shoreline.
- Moderate (2): An area that exhibits slight resource damage with complete recovery potential. Example: tuna fishery.
- High (3): An area that exhibits moderate resource damage with only partial recovery potential. Example: clam beds.
- Extreme (4): An area that exhibits high resource damage with little recovery potential. Example: valuable crab dredging area.

Replacement or Restoration Costs Guidelines--

This value considers both the replacement cost for physical structures damaged by oil contamination and complete or partial restoration costs for a

TABLE 7. ECONOMIC VALUES

	Increasing Sensitivity →			
	low 1	moderate 2	high 3	extreme 4
INCOME OR USE REDUCTION	No income or use reduction potential.	Slight income or use loss or reduction.	Moderate income or use reduction or loss.	Total income or use loss.
NATURAL RESOURCE DAMAGE	No resources damage.	Slight resources damage or degradation.	Moderate resources damage or degradation.	Severe resource damage or degradation.
REPLACEMENT AND RESTORATION COSTS	Only natural restoration necessary.	Minimal replace- ment or restora- tion required with natural actions.	Moderate replace- ment or restora- tion required with natural actions.	Extreme replacement or restoration required without natural actions.

natural or developed area. If an area or structure can be naturally restored by wind and water actions, the costs are essentially nonexistent. Only costs for manpower and equipment are to be considered.

- Low (1): An area that would not require restoration or replacement of structures by man after oil contamination. Example: open ocean.
- Moderate (2): An area that would require minimal replacement of structures or restoration. Example: sailboat marina.
- High (3): An area that would require moderate replacement of structures or restoration. Example: wildlife reserve.
- Extreme (4): An area that would require extensive replacement of structures or restoration or an area that cannot be restored by man. Example: waterfowl rookeries.

Social Water Use Values (Step F4)

Other values that determine the relative importance of sensitive water use are composed of two general categories: consumptive uses and nonconsumptive uses. Consumptive use is defined as the portion of the withdrawal from a water source not directly returned to the water source. Nonconsumptive use is defined as the use of a water source for a purpose that does not consume water (that is, withdrawal equals return).

This type of information can be obtained through visual reconnaissance and individual interviews, and only general guidelines are presented here.

The guidelines below will aid the OSC in assessing the social water use values:

- purpose of use
- effect of oil on use
- degree of direct contact
- amount of use
- treatment present before use of water

Table 8 presents a matrix of social water use values.

Purpose of Water Use Guidelines--

This value considers the purpose of water use when withdrawn for consumptive use. It assumes that water for direct human consumption is more sensitive than water for non-human consumption.

- Low (1): The water is used for non-drinking purposes without direct contact. Example: ground water recharge.
- Moderate (2): The water is used for non-drinking purposes but with some direct contact. Example: washing clothes or automobiles.

TABLE 8. SOCIAL WATER USE VALUES

	Increasing Sensitivity →			
	low 1	moderate 2	high 3	extreme 4
PURPOSE OF USE	Non-drinking/ no direct contact.	Non-drinking/ direct contact.	Non-drinking/ irrigation or industrial use.	Drinking water supply.
EFFECT ON USE	No effect.	Some effect but no change.	Great effect but use still possible.	Unfit for any use.
DEGREE OF DIRECT CONTACT	None.	Minimal.	Some.	Total (i.e., submersion).
AMOUNT OF USE	<100 gallons per day or <100m ² surface area.	<5,000 gallons per day or <1,000m ² surface area.	<100,000 gallons per day or <10,000m ² surface area.	>100,000 gallons per day or >10,000m ² surface area.
TREATMENT PRESENT BEFORE USE	Physiochemical.	Chemical.	Physical.	No treatment.

- High (3): The water is used for non-drinking purposes such as industrial or irrigation uses. Example: crop irrigation.
- Extreme (4): The water is used for human or animal drinking water supply. Example: municipal water supply.

Effect of Oil on Use Guidelines--

This value relates the contamination of the water resource to the ability of the user to use the oil/water mixture without harm or adverse impacts. It assumes that some water uses will be affected by the presence of oil, while some water uses will not.

- Low (1): The presence of oil does not affect area uses of water. Example: motor boating.
- Moderate (2): The presence of oil will affect the area uses to some degree, but not enough to cause concern. Example: fishing.
- High (3): The presence of oil will affect the area use to a great degree, but use is still possible. Example: industrial cooling water.
- Extreme (4): The presence of oil would make an area unfit for use of any kind. Example: drinking water.

Degree of Direct Contact Involved in Water Use Guidelines--

This value relates the degree of direct contact (human or animal) that occurs when the area is used for any purpose. It assumes that the more direct contact of oil with biological organisms, the more potential for adverse impact.

- Low (1): The users do not have direct contact with the oil/water mixture. Example: power generation intake.
- Moderate (2): The users have minimal direct contact with the oil/water mixture. Example: motor boating.
- High (3): The users have some direct contact with the oil/water mixture. Example: fishing or sailing.
- Extreme (4): The users have total direct contact (that is, submersion) in the oil/water mixture. Example: swimming or water skiing.

Amount of Water Use Guidelines--

This value assumes that the more water used, the greater the potential for damage. This is either total surface area used for nonconsumptive purposes (for example, swimming) or total volume used from an area.

- Low (1): The area is used to supply a minimal volume (less than 100 gallons or 380 liters per day) of water or a small surface area is present (less than 100 m²). Example: private water supply.
- Moderate (2): The area is used to supply a small volume (less than

5,000 gallons or 19,000 liters per day) of water or a moderate surface area is present (less than 1,000 m²). Example: small irrigation intake.

- High (3): The area is used to supply a large volume (less than 100,000 gallons or 380,000 liters per day) of water or a large surface area is present (less than 10,000 m²). Example: small domestic water supply.
- Extreme (4): The area is used to supply a great volume (more than 100,000 gallons or 380,000 liters per day) of water or an extremely large surface area is present (more than 10,000 m²). Example: industrial process water.

Treatment Present Before Use of Water Guidelines—

This value assumes that if treatment is present before use, no adverse impacts will occur to the user.

- Low (1): The water treatment before use is equivalent to tertiary treatment. Example: physiochemical treatment (that is, carbon filtration).
- Moderate (2): The water treatment before use is equivalent to secondary treatment. Example: chemical treatment (that is, precipitation).
- High (3): The water treatment before use is equivalent to primary treatment. Example: physical treatment (that is, sedimentation).
- Extreme (4): No water treatment is present before use. Example: raw water use.

OUTSIDE CONSIDERATIONS (STEP F5)

During a spill incident, factors external to actual spill dynamics and area values may affect the spill response and the order of priorities. These are (1) political pressures, (2) public pressures, and (3) time restrictions. The rating format is identical to that for sensitivity values, as shown in the matrix in Table 9. Rating the outside considerations should be performed after the area sensitivities are known. The OSC must be aware of their existence because while sometimes difficult to detect, they may heavily influence spill response patterns. Ideally, outside considerations should all rate low (1), but situations can arise where this will not be true.

Political Pressure Guidelines

Pressure resulting from non-cooperation or influential requests may alter the OSC's plan for handling a spill incident. This external pressure may be exerted by local, regional, county, state, or Federal enforcement officials or other influential parties. While cooperation is the norm, and enforcement personnel will concur most of the time, this value allows for those incidents where cooperation is not available or where political pressure dictates a different response than originally planned.

TABLE 9. OUTSIDE CONSIDERATIONS

INCREASING MAGNITUDE 				
	low 1	moderate 2	high 3	extreme 4
POLITICAL PRESSURE	Either high level of cooperation, or low level of objection. No pressure for selected area.	Some cooperation, or some objection. Some pressure for selected area.	Little cooperation or high objection. Moderate pressure for selected area.	No cooperation - strong objection. Strong pressure for selected area.
PUBLIC PRESSURE	No public interest.	Some public pressure; strong individual pressure.	Moderate public pressure; high public awareness.	Strong public pressure and private interest group concern.
TIME RESTRICTIONS	Can take as long as is necessary.	Some time restriction, but not requiring 24 hour effort.	Some time restrictions requiring 24 hour effort.	Severe time restrictions.

- Low (1): An area where either there is good cooperation or no objection to response activities. Also, there is no outside pressure for action from interested parties.
- Moderate (2): An area where there is reluctant cooperation or some objection but insufficient pressure to interfere with spill response efforts. However, there is some pressure to perform actions from interested parties.
- High (3): An area that generates little cooperation in other areas, some objection, and moderate external pressure for action, which might interfere with spill response efforts.
- Extreme (4): An area that generates negative cooperation (that is, obstruction of duties) in other areas, organized objections, and strong external pressure for actions that interfere with the spill response efforts.

Public Pressure Guidelines

Public awareness of oil pollution and public interests may be of importance during an oil spill response. The public may include affected parties such as land owners or boat owners, groups of concerned citizens, organized environmental groups, and industrial companies.

An area may be rated high based upon the public reaction and demand for immediate and complete cleanup. Alternatively, an area may be of special significance to an individual or group. This value is extremely spill- and site-specific. It may be difficult to determine at the onset of a spill response, and only become obvious after adequate public or private interest has been generated by the spill.

- Low (1): An area that does not generate public interest (that is, indifference) or no special interests are involved.
- Moderate (2): An area that generates some public awareness but minimal pressure for action and only individual interests are strong.
- High (3): An area that generates moderate public pressure and private interest group concern.
- Extreme (4): An area that generates strong public pressure and private interest group concern.

Time Restrictions Guidelines

Time is a possible constraint and may play an influential role in the spill response. Although an OSC always tries to handle a spill response in a timely manner, some circumstances dictate extraordinary actions or methods.

- Low (1): Time plays no role in the spill response efforts.

- Moderate (2): There are some time restrictions, such as opening a harbor to traffic, but none that require additional manpower or extra shifts seven days a week.
- High (3): There are some time and manpower restrictions that have an effect on the spill response efforts. For example, when there are two spill incidents and insufficient personnel, when there is a spill affecting a resort beach during peak season, or when a highly sensitive area is threatened.
- Extreme (4): There is a severe shortage of time that dictates using more manpower and/or equipment than would normally be used. Examples are an oil spill occurring just prior to a long holiday weekend in a resort area that depends on the weekend for financial stability, or a spill occurring when a drastic weather change is projected, or a spill that endangers an extremely sensitive area.

Other Outside Considerations

The two other outside considerations that may be of concern to the OSC are (1) legal pressure and constraints, and (2) the news media. Neither of these can be defined well enough to adequately rate them numerically for all situations. Therefore, they are discussed so that the OSC is aware of them and he may alter his priorities because of them if he deems them important enough.

- Legal pressure and constraints can be introduced into a spill situation when certain laws or local regulations hamper response efforts. These include: (1) trespassing, (2) injunctive actions, (3) non-response from spiller, and (4) conflicting regulatory jurisdictions. Even though the OSC duties are legally mandated, legal pressures may arise, and the OSC must be able to deal with them.
- The news media may enter any spill situation. In gathering information about the spill, the press may either cooperate with the OSC or may be overly persistent and even interfere with the spill response. Reporters even potentially endanger themselves, members of the spill response team, or the response itself. Therefore, the OSC must control press activities and provide updated truthful press releases and interviews when necessary.

SECTION 6

PRIORITY DETERMINATIONS

INTRODUCTION

In determining protection and cleanup priorities, problems and conflicts will frequently arise. Equipment, manpower, time, and other needed resources are usually limited, especially in the early phases of an oil spill, making it impossible to devote equal effort to all areas simultaneously. Hopefully, in a minor spill (less than 1000 U.S. gallons or 24 bbl) situation, the majority of the areas can be protected and cleaned up concurrently. However, the larger the spill, either in volume or area covered, the larger the potentially affected areas. This results in decreased ability of the OSC to gather and allocate resources to address adequately all necessary control and counter-measures.

The OSC has the primary responsibility to decide which threatened areas should be protected and in what order they should receive attention. This is the first priority. Cleaning up already contaminated areas is a secondary consideration.

Decisions made by the OSC must be based on information that is accurate, detailed, complete, updated, and unbiased. In addition, it must be gathered and assessed quickly and efficiently.

This section provides a systematic approach to the establishment of priority actions. It includes:

- a preliminary, quick-screening mechanism to be used when time is extremely limited
- a numerical rating system to be used to determine the relative sensitivities (including the outside considerations) of all areas under investigation
- the establishment of protection priorities for threatened areas
- the establishment of cleanup priorities for affected areas.

PRIORITY SCREENING

In certain spill situations, a need arises for a quick preliminary overview of the entire potentially affected region. This may be because of (1) severely ~~limited~~ time resulting from late arrival on scene, (2) the large

number of areas in the region involved, or (3) inadequate information on areas for the decision-making process. This screening system is based solely on the known sensitive components of the environment that are likely to be encountered in an oil spill response. It assumes constants such as (1) all areas will be damaged equally if affected, (2) a non-relative classification of extreme sensitivity or no sensitivity, and (3) all values (that is, economic and ecological) are of equal importance to the affected communities. For these reasons and others, this screening system should not replace the more flexible and accurate numerical rating process.

The OSC should realize that if this screening system is used to establish priorities, a complete reassessment using the numerical rating system should be performed when conditions permit. This will ensure that correct priorities were established and that the effects of the oil spill were minimized as much as possible.

The following values make an area extremely sensitive to oil contamination. Any area under investigation that exhibits one or more of these values is considered a priority area. The more values it has, the more sensitive it is. The OSC must rely on his experience and judgment in deciding which values are more important on a spill-specific basis.

Environmental Values

- any area with excellent water quality that would experience habitat modification for up to one year
 - trout streams
 - coral reefs
 - sand beaches
 - tidal mud flats
 - salt marshes
 - mammal rookeries
 - areas of beach stabilizing vegetation

Ecological Values

- any area that exhibits a high diversity of permanent residents, such as juvenile or larval forms, seedlings, diving ducks, auks or sea otters
- any area that is highly productive with a complex food web having man as the top consumer
- any area that supports endangered species
 - rare, threatened, endangered, or protected species habitat
 - waterfowl rookeries
 - mangrove swamp
 - eelgrass beds
 - fisheries
 - shellfish harvesting area

- coral reef
- mammal calving ground
- kelp beds

Aesthetic Value

- any extensively used area with unique natural features, beautiful vistas, or wilderness qualities where oil would be highly visible and would generate strong local concern
 - archaeological study area
 - tribal fishing area
 - historical site
 - observation site in parklands
 - views from major highways
 - reserves, preserves, and other legally protected areas
 - state parks and beaches
 - Federal parks and wilderness lands
 - resort beaches

Economic Values

- any area that would undergo extensive resource damage that would result in great or total loss of income or use
- any area that would require extensive structural replacements or land restoration
 - heavily harvested fisheries or shellfish bed
 - marinas and boat harbors
 - recreational beaches
 - resort beaches
 - endangered species habitat
 - recreational lake
 - industrial process water intake
 - aquaculture areas

Social Values

- any area that is used for large non-consumptive water use where direct contact (for example, submersion) occurs and oil would render it unusable
- any area that is used as a human or animal drinking water supply with no prior treatment
 - cooling water intakes
 - process water intakes
 - domestic and irrigation water supply
 - swimming, skiing, or surfing beaches

If no extremely sensitive areas are ascertained from the screening process,

the user should proceed to the numerical rating system to find the relative sensitivities of the areas investigated.

NUMERICAL RATING SYSTEM

The values in Section 3 have been developed to simplify the decision-making process used by the OSC during an oil spill emergency response. These values allow for variability in the subjective judgments of individual OSCs during an oil spill incident. The two aspects of a spill incident to which these values apply are as follows:

- environmental (Step F1), aesthetic (Step F2), economic (Step F3), and social (Step F4) entities of an area
- outside considerations (Step F5)

The relative sensitivity range of these values is from one (1) (least sensitive: most tolerant) to four (4) (most sensitive: least tolerant). The four levels of sensitivity are described below. A zero (0) can also be assigned when the value in question does not apply to the area being rated; for example, an area may not have any water uses or any significant population.



If the user does not have enough knowledge of a particular value to make a sound judgment, he may arbitrarily assign a one (1) assuming a low level of sensitivity. This will tend to lower the overall sensitivity of the area, thus indicating the lack of obvious sensitive components in that area.

The "Sensitivity Rating Worksheet" (Table 10) can be used to rate areas for all values. The mathematics are fairly straightforward, but the use of a calculator will simplify and speed up the process. The following steps are to be used:

Rating of Sensitivity Values (Steps F1-F4)

- Rate each value from zero (0) to four (4) depending upon the area's sensitivity. It is advisable to rate more than one area at a time since it is easier to make comparative judgments than single estimates of sensitivity.
- Add the numbers for each section together to get a section subtotal.
- Add all these subtotals for all sections to derive the total sensitivity rating for an area. The possible range of values is from 0 to 64. The higher this total sensitivity rating, the more sensitive the area is to oil contamination.

Rating of Outside Considerations (Step F5)

- Rate each value from zero (0) to four (4) depending upon the degree of

TABLE 10. SENSITIVITY RATING WORKSHEET (STEP F)

VALUES	Rating Range	SENSITIVE AREAS							
		A	B	C	D	E	F	G	H
STEP F1 ENVIRONMENTAL									
• Water Quality Degradation	0-4								
• Biological Productivity	0-4								
• Unique Habitat Uses	0-4								
• Ecological Vulnerability	0-4								
F1 Subtotal	0-20								
STEP F2 AESTHETIC									
• Scenic Quality	0-4								
• Visual Impact	0-4								
• Local Appreciation	0-4								
F2 Subtotal	0-12								
STEP F3 ECONOMIC									
• Income or Use Reduction	0-4								
• Natural Resource Damage	0-4								
• Replacement/Restoration Costs	0-4								
F3 Subtotal	0-12								
STEP F4 SOCIAL									
• Purpose of Use	0-4								
• Effect of Oil	0-4								
• Degree of Direct Contact	0-4								
• Amount of Use	0-4								
• Treatment Before Use	0-4								
F4 Subtotal	0-20								
TOTAL SENSITIVITY RATING	0-64								

outside pressure present for each area using Table 11.

Modified Total Area Sensitivity Rating (Step F6)

- Outside considerations are rated to modify or reorder the previously established sensitivities by adding the outside consideration rating to the area sensitivity rating from Steps F1-F4 in Table 11.

Modified Total Area Sensitivity Ranking (Step G)

- The modified total sensitivity rating for each area is ranked 1 through 8 (variable) in order of decreasing sensitivity on Table 11.
- Use modified total sensitivity rankings to establish priorities for both protection and cleanup actions.

PROTECTION PRIORITIES

After the relative sensitivities have been determined by use of the ranking system in Step G, the establishment of protection priorities should be performed. The protection of uncontaminated areas should be performed before any cleanup effort is applied to previously affected areas. This strategy will ensure that the adverse impacts from the oil spill will be minimized as much as possible.

Decision-making involves four basic components:

TABLE 11. AREA SENSITIVITY RANKING

VALUES	Rating Range	SENSITIVE AREAS							
		A	B	C	D	E	F	G	H
STEP F5 OUTSIDE CONSIDERATIONS									
● Political Pressure	0-4								
● Public Pressure	0-4								
● Time Restrictions	0-4								
F5 Subtotal	0-12								
TOTAL SENSITIVITY [F1-F4]	0-64								
STEP F6 TOTAL MODIFIED SENSITIVITY	0-76								
STEP G SENSITIVITY RANKING	(1-8)								

- area sensitivity rating (Steps F1-F4)
- outside considerations (Step F5)
- predicted order of contamination (Step H)
- ability of the area to cleanse itself (vulnerability index) (Step I)

The first two components have previously been discussed in detail. The combined rating for components [modified total sensitivity rating (Step G)] is used together with the predicted order of contamination (Step H) and the area vulnerability index (Step I) to determine protection priorities.

Predicted Order of Contamination (Step H)

The predicted order of contamination of the sensitive areas is determined by the use of the spill dynamics discussed in Section 3. By applying this information and plotting the spill areas (Section 4) on a topographic map of sufficient detail, an estimation of the temporal order of contamination can be determined. The areas should be ranked as to which will be affected first (1), second (2), third (3), etc., if no protective countermeasures are employed. If two or more areas will be affected at approximately the same time, because of proximity or a fast-moving slick, the same rating can be given to all. These ratings are applied to the protection priority determination method under Step H in Table 13.

Area Vulnerability Index (Step I)

This index is based primarily on the relative persistence of spilled oil within each of 12 physical environments assuming only natural cleaning actions. The persistence of the oil is based on these factors: (1) the nature of the sediments (that is, relative grain size), (2) the energy of the nearshore processes, and (3) the general local climate. A rating of 0.5 indicates the oil will persist for many years, whereas a ranking of 6.0 means natural clean-up will occur rapidly.

Table 12 (modified from Gundlach and Hayes, 1978) shows the vulnerability index for the most common area types based on the shoreline components encountered in a spill response. The OSC should determine which component is the most dominant within the area and assign ratings accordingly. The area vulnerability index for each area is rated and recorded in Step I of the priority determination chart in Table 13.

Priority Determination (Step J)

The final determination of protection priorities involves the summing of all the previously obtained ratings for (1) Step G - modified total sensitivity (including outside consideration), (2) Step H - predicted order of contamination, and (3) Step I - the area vulnerability index. This is a straightforward process and should be performed using Table 13.

This system should be used by the OSC to allocate resources to areas with

TABLE 12. AREA VULNERABILITY INDEX (STEP 1)

Vulnerability Index	Components	Persistence	Comments	U.S. Analogs
6.0	Open waters.	Few days.	Waves and currents will dissipate oil sufficiently.	
5.5	Exposed rocky headlands of man-made structures.	Few days to a few weeks.	Wave reflection keeps most of the oil off-shore.	California, Oregon, southeast Alaska.
5.0	Eroding wave-cut platforms.	Few days to a few weeks.	Wave-swept. Most oil removed by natural processes within weeks.	Maine, Washington.
4.5	Flat, fine-grained sand beaches.	1-6 months.	If oil penetrates into the sediment it may persist several months.	South Carolina barrier islands.
4.0	Steeper, coarse-grained sand beaches.	1-6 months.	Oil may sink and/or be buried rapidly, making clean-up difficult. Under moderate to high energy conditions, oil will be removed naturally within months from most of the beachface.	Outer Cape Cod, Cape Hatteras.
3.5	Exposed, compacted tidal flats.	Less than 1 year.	Most oil will not adhere to, nor penetrate into, the compacted tidal flat.	Georgia estuaries, New England estuaries.
3.0	Mixed sand and gravel beaches.	Less than 1 year.	Oil may undergo rapid penetration and burial. Under moderate to low energy conditions, oil may persist a year.	Most Alaskan beaches.
2.5	Gravel beaches.	1-8 years.	Same as above. A solid asphalt pavement may form under heavy oil accumulations.	Maine, New Hampshire.
2.0	Coral reef.	Variable.	Corals either exposed or near the surface would suffer greatest damage.	Florida Keys, Puerto Rico, the Virgin Islands.
1.5	Sheltered rocky coasts.	1-8 years.	Areas of reduced wave action. Oil may persist for many years.	Maine, southeast Alaska.
1.0	Sheltered tidal flats.	More than 10 years.	Areas of great biologic activity and low wave energy. Oil may persist for years. These areas should receive priority protection by using booms or oil sorbent materials.	South Carolina estuaries.
0.5	Salt marshes and mangroves.	More than 10 years.	Most productive of aquatic environments. Oil may persist for years. Protection of these environments by booms or sorbent material should receive first priority.	East Coast estuaries.

(Modified from Gerdloff and Hayes, 1978, and Michael, Hayes, and Brown, 1978.)

TABLE 13. PROTECTION PRIORITY DETERMINATION (STEP J)

Identified Threatened Areas	Step G	Step H	Step I	Step J
	Total Area Sensitivity Ranking	Predicted + Order of Contamination	Area + Vulnerability Index	Protection Priority Ranking (F, H, + I)
Area A				
Area B				
Area C				
Area D				
Area E				
Area F				
Area G				
Area H				

the lowest numerical ranking first. As soon as these high-priority areas are adequately protected, the effort should proceed to lower priority areas. If an area is ranked at the higher end of the scale it is (1) least sensitive, (2) least difficult to clean up, and (3) last to be contaminated (if at all). The OSC must decide if he should protect such areas at all or should allocate resources to cleanup operations in contaminated areas.

Priorities assigned to protection actions are based on the following logical decisions:

- An area may be more sensitive but still can be ranked lower than a less sensitive area. For example, if oil will not contaminate the area for a while, efforts should first be directed to less sensitive areas that can be protected relatively quickly, then applied to the more sensitive area.
- An area that is first to be contaminated may receive a lower ranking because of its low sensitivity. The main effort should, therefore, be directed to more sensitive areas since the effort involved to protect the first affected area may not be worth the benefit received or timely enough to protect it fully.
- If two or more areas receive the same priority ranking, the OSC should place a higher priority on the more sensitive areas.

- Since this is a relative scale, if one area shows a drastic difference in sensitivity or time of impact, or area vulnerability over all other areas, these priority rankings should be adjusted.

CLEANUP PRIORITIES

After all threatened areas have been adequately protected, the spill dynamics must be reassessed to confirm that no additional areas will be contaminated because (1) the total spill volume is inadequate to spread further, (2) the wind and current have ceased spreading oil, (3) no more areas are within the spill trajectory, or (4) oil is sufficiently dissipated to render damage potential negligible. The main effort must now focus on cleaning up the already affected zones. The general order of priorities should be as follows:

1. Clean the heavily oiled waters surrounding protected sensitive areas to ensure continued protection.
2. Clean all sensitive areas that have been contaminated.
3. Clean heavily oiled open waters (if possible).
4. Clean nonsensitive contaminated areas, if present.

This sequence of actions will apply to most spill situations, but the OSC may have to reorder cleanup priorities because of such factors as:

- the presence of an extremely sensitive area that has undergone heavy contamination prior to implementation of protective measures
- abrupt and drastic changes in spill dynamics because of weather conditions
- lack of proper equipment to perform specific area cleanup
- inadequate protection countermeasures
- infeasibility of open water cleanup
- recurrence or continuation of spill
- outside influences that alter in-field priorities

Cleanup activities should take place only when it will help to minimize the ecological impacts of a spill on a sensitive area. Some biologically sensitive areas such as salt marshes and mangroves swamps will be impacted more by cleanup activities than the presence of oil. The natural cleanup (that is, no man-induced activities) should always be considered. More guidance on natural restoration is given in Section 9.

Factors Affecting the Cleanup Process

Factors affecting the cleanup process include (1) the modified total area sensitivity, (2) the degree of contamination, (3) the vulnerability or self-cleaning ability of the area, and (4) the wave energy of the surrounding waters. The area sensitivity and the vulnerability are rated exactly the same as the protection priority determinations. Obviously, the same areas will not be rated for both protection and cleanup if the protection methods are effective. The degree of contamination and the wave energy index are unique to the establishment of cleanup priorities since both determine the level of manpower effort required.

Degree of Contamination (Step P)

The degree of oil contamination of an area depends upon (1) the total surface oiled, (2) the thickness of the oil coating or slick, and (3) the depth of penetration on land surface or in the water column. Since cleanup actions may be necessary on land surfaces as well as water bodies, both are rated in Table 14. More than one area should be rated simultaneously since it is a relative rating scale.

TABLE 14. DEGREE OF CONTAMINATION (STEP P)

Rating	For Land Area	For Water Area
1	very heavily oiled; deep penetration (>25 cm).	thick oil slick (>2 μ m); dark brown in color.
2	heavily oiled; some penetration (>10 cm).	continuous slick (>1 μ m); dull colors.
3	moderately oiled; slight penetration (>0.3 cm).	pockets of oil (>0.2 μ m); bright colors.
4	slightly oiled; only minor surface penetration (<0.3 cm).	thin film of oil (<0.2 μ m); slight traces of color.
5	very minor oiling; only on surface.	barely visible as sheen on water surface.

Wave Energy Index (Step Q)

The wave energy index is based on (1) the height of the waves (dependent on current and wind speed), (2) angle of wave fronts, and (3) the relative degree of shelter present. This index is mainly developed for land surfaces adjacent to water bodies but can also be used for open water situations for conditions present at the time of cleanup. There are three general levels of classification, and these are described in Table 15.

TABLE 15. WAVE ENERGY INDEX (STEP Q)

Rating	Wave Energy	Area Description
1	low	few or no waves, <0.3 m (0-1 ft); sheltered from direct waves; waves at angles.
2	medium	moderate waves, 0.3-1 m (1-3 ft); partially sheltered; waves either direct or at an angle.
3	high	high waves, >1 m (>3 ft); unsheltered; direct waves.

Priority Determination

The final determination of cleanup priorities involves summing all previously obtained ratings for (1) modified total area sensitivity (Step G), (2) the degree of contamination (Step P), (3) the area vulnerability index (Step I), and (4) the wave energy index (Step Q). This is a straightforward process and should be performed using Table 16.

This priority ranking should be used as a guide for the OSC in allocating resources to top-priority areas. After these areas have been adequately cleaned up (see Section 10 for guidelines), the lower priority areas should be assessed to see if cleanup is necessary. These low-priority areas are (1) least sensitive, (2) least contaminated, (3) least vulnerable, and (4) possess high wave energy. The OSC should determine (with the guidelines in Section 9) if these areas require attention. In some cases the best action is no action.

Assigning priorities for cleanup action should rely on the following logical decisions:

- An area may be more sensitive but can rank lower than a less sensitive area because of less contamination or higher natural cleansing action.
- An area may be the more contaminated but rank lower than a less contaminated area because it is less sensitive or has higher natural cleansing action.
- An area that has the highest natural cleansing potential may be ranked higher than a low energy system because of greater sensitivity or higher contamination.
- If two or more areas receive the same priority ranking, the OSC should place a higher priority on the more sensitive areas.
- Since this is a relative scale, if one area shows a drastic difference in sensitivity, degree of contamination, vulnerability, or wave energy,

TABLE 16. CLEANUP PRIORITIES DETERMINATION (STEP R)

	(Step G)	(Step P)	(Step I)	(Step Q)	(Step R)
Identified Affected Areas	Total Area Sensitivity + Ranking	Degree of Contam- ination	Area Vul- nerability + Index	Wave Energy = Index	Priority Ranking (Steps G + P + I + Q)
Area A					
Area B					
Area C					
Area D					
Area E					
Area F					
Area G					
Area H					

over all others, priority rankings should reflect this and be adjusted so that differences are taken into account.

After the cleanup priorities have been established, the OSC must determine the best practical cleanup systems available. Guidelines for this are found in Section 9.

SECTION 7

BEST PRACTICAL CONTAINMENT METHODS (STEP D)

INTRODUCTION

Containment measures are the first actions taken during an oil pollution incident. They include actions to eliminate the flow and limit the release and spread of oil. This manual deals with oil released into any waters of the United States. Typical containment actions might include:

- isolating and/or evacuating the spill area to reduce the exposure limits and protect personnel
- eliminating the flow of oil, which may involve shutting off a valve or extensive salvage operations
- placing barriers to prevent oil from contacting sensitive areas

Speed and effectiveness in using containment measures will reduce the impact of the spill incident. However, there is no "perfect" oil containment plan; each has its advantages and disadvantages. This manual aids the user in recognizing the most effective containment method for each spill incident. Table 17 summarizes the most commonly used containment methods.

This manual refers to equipment by type rather than by manufacturer's trade name and only differentiates between the different types of products. No distinction between similar products by different manufacturers is made.

BOOMS

The most common containment device is the boom. It can either be commercially purchased or improvised from available materials. In general, the structure of a boom has four basic components: (1) a means of flotation, (2) a freeboard to prevent waves from washing oil over the top, (3) a skirt to prevent waves from sweeping oil under, and (4) a longitudinal support member to withstand the force of waves, winds, and currents. A fifth component may also be present. This is a ballast that adds weight to the boom and helps keep it perpendicular to the water surface. There are several common configurations for commercially available booms as shown in Figure 5.

Forces caused by the action of wind, waves, and current either singly or in combination can cause any boom to fail in its intended function. Some types of boom failure are:

TABLE 17. SUMMARY OF CONTAINMENT METHODS

Type of System	Principle of Operation	Advantages	Disadvantages	Application
Sorbent Barrier	Both a physical barrier and an absorbent surface.	Easily deployed. Used for both containment and cleanup.	Works best in calm water such as harbors. Oil not effectively contained. Requires support to avoid breakage under flow of water. Requires means of flotation to prevent sinking when saturated with oil and water. Requires care in removing from water to protect oil loss and area recontamination.	Calm waters where the oil slick is thin.
Air or water hose spray	Forms turbulent barrier.	Can be rapidly applied.	Effective in calm waters (current <0.5 knots).	To keep oil out of an area, to flush oil from under a dock. As a temporary containment measure.
Surface	Surface tension phenomenon; the spreading force of the chemical is sufficient to overcome the spreading force of the oil.	Easily applied. Small doses required.	Provides limited containment. Requires government approval before using. Effective in calm waters.	Oil may be moved ahead of the spreading film toward a containment device. The oil spreading rate may be slowed by encircling the slick with the piston film. These are useful to help to concentrate and direct the "rainbow" sheen into a skimmer.
Air Barriers	Subsurface release of air to create an upwelling on the water surface so that oil will not cross the two-way current produced where the bubble curtain meets the surface.	Does not impede movement of vessels.	Costly to install and maintain. Limited by environmental factors (wind, current). High power requirements to produce sufficient air currents. May cause redistribution of bottom silt.	Suited to calm waters such as harbors. Can be used to contain oil (calm waters) or divert the oil (low current) to an oil recovery point.
Booms	A physical barrier serving as a solid, continuous obstruction to the spread or migration of an oil slick.	Deployed quickly. Are physical barriers.	Do not work well in fast currents or rough seas. Can impede vessel movement.	(Class I - calm water) (Class II - harbors) (Class III - open water) To enclose the oil and reduce the spreading rate. To protect areas from oil contamination. To divert oil to areas for recovery.

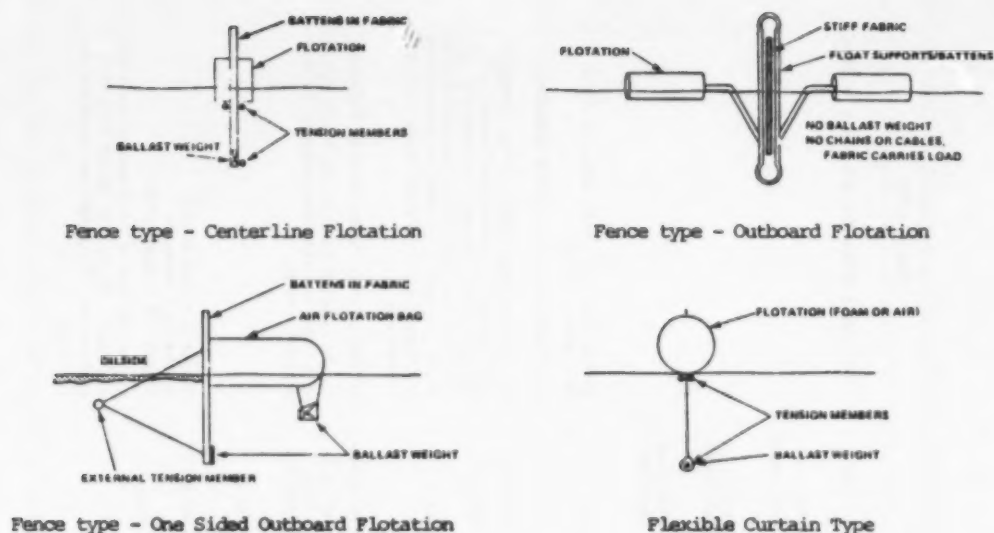


Figure 5. Boom types.

- Sheet breakaway or drainage failure: oil flowing under the boom because the oil slick is deeper than the boom skirt.



- Splash-over: oil splashing over the boom because of wind or wave action.



- Headwave failure or droplet breakaway: sufficient oil is stopped upstream of a boom and thickens to form a headwave at the upstream edge of the slick. The action of the water velocity at the oil-water interface causes sufficient turbulence to allow oil globules to break away and be carried under the boom by the current.



Generally, booms are the first equipment to be deployed and the last to be retrieved. Therefore, for effective oil containment they must be properly selected and correctly deployed. Boom selection and placement are briefly covered here. The user is directed to the references for more in-depth discussions.

Boom Selection

For effective containment, the boom selected for a particular spill application should be compatible with the water conditions in which it will be used. Booms are available in several different sizes. For simplicity, the U.S. Navy has divided booms into three classes based upon the size of the skirt and freeboard (Table 18). Each class is suitable for different wave and current conditions.

Boom Placement

Regardless of the boom class, all booms begin to lose oil when placed perpendicular to currents exceeding 0.7 knots (36 cm/sec). General guidelines are given for boom deployment below and summarized in Table 19. It must be emphasized that field observations are the best guide to the effectiveness of a boom configuration.

In offshore use, one of the most effective deployment strategies is the V- or U-shape. In this deployment strategy, the apex is downwind and each free boom end is restrained by an anchor, a boat, or similar device. This allows the oil to move into the apex where it is concentrated for removal as shown in Figure 6.

TABLE 18. U.S. NAVY BOOM CLASSIFICATION

Class	Skirt Depth (inches)	Freeboard (inches)	Total Height (inches)	Use	Current Velocity Perpendicular to Boom (knots)	Wind Velocity Perpendicular to Boom (mph)	Wave Ratio height/length
I	8	4	13	Calm waters	1.0	15	0.08
II	16	8	24	Harbor (moderate waves and current)	1.5	20	0.08
III	24	12	36	Open water	2.0	25	0.08

Source: Naval Facilities Engineering Command, 1977.

TABLE 19. GUIDELINES FOR CONTAINMENT DEVICES AND METHODS

Location	Water Condition	Objectives	Possible Methods
Open Water Water Depth <6 m (20 ft.) Inland or Ocean	Wave Height: <2.5 m (8 ft.)	- Rough water; too rough for effective spill response. - Protect areas from contamination.	- Stand by for calmer sea conditions. - Activate shoreline protection response.
	Wave Height: 1-2.5 m (3-8 ft.) Current: 50.8 m/sec (11.5 knots) (80 cm/sec)	- Estimate oil slick area. - Reduce oil spreading. - Contain oil. - Prevent shoreline contamination.	- Dispatch observation vessel, boat or air, to: - estimate extent of oil slick - retard and reduce oil slick by use of surface collecting agents - Use large vessel-type skimmer to contain and collect oil -- deploy Class III Booms in V-shape.
		or	
Coastal Waters	Wave Height: 1-2.5 m (3-8 ft.)	Protect shoreline.	- Use medium skimmer with Class III Boom in U-shape (catenary) between two tow boats. Skimmer should be down at apex. - Deploy booms beyond surf area. - Activate shoreline protection response.
Protected Waters Harbor	Wave Height: 0-1 m (0-3 ft.) Current: (low) <0.8 m/sec. (1.5 knots)	- Contain oil spill and prevent oil contamination of difficult (and costly) areas to clean such as dock pilings. - Locate skimmers, preferably in stationary positions down-drift of contained oil.	- Use bubble barrier if installed. - Deploy booms between vessel and dock. - Apply water streams or air jet in zig-zag manner to concentrate the slick (applying these directly on oil would cause emulsification). Use of sorbent pads on upwind slick edge will increase efficiency due to increased sail area. - Use boat propwash to push oil toward the skimmer. - Move booms to reduce boom area and increase oil thickness. - Use surface collection agent and sorbent to remove sheen.

(Continued)

TABLE 19 (CONTINUED)

Location	Water Condition	Objectives	Possible Methods
<u>Protected Waters</u>			
River	Wave Height: 0-0.3 m (0-1 ft.)	• Divert oil from high current into low current areas. • Protect shoreline.	• Angle boom to current; position portion of boom along shore to reduce contamination. Recover oil by using skimmers.
Tidal-Influenced waters	Wave Height: 0-1 m (0-3 ft.)	• Contain oil during ebb and flood tides.	• Boom upstream and downstream of spill with skimmers located in both areas.
Stream	Wave Height: 0-0.3 m (0-1 ft.)	• Contain oil.	• Construct wire boom out of chicken wire and a sorbent material, wood, or pipe.

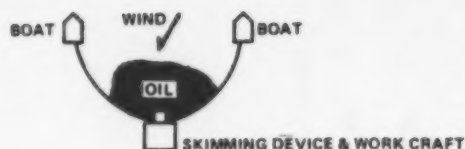


Figure 6. Vee configuration for open water collection.

In sheltered areas, the deployment configuration depends upon current, wave conditions, and tidal influences. Current velocities are not equal in flowing water bodies, usually having higher velocities in the deeper portions of a channel and along the outside of curves. Boom placement should be at an angle to these currents so as to divert oil to calmer waters for recovery. There are several boom deployment configurations for these conditions such as the chevron-shape deployment (Figure 7), or the cascading boom deployment (Figure 8), or in calmer waters, the diagonal deployment (Figure 9). When booms are deployed in waters with tidal influences, they should be checked frequently to ensure effective oil containment.

In areas where no commercial boom is available, improvised booms made of straw, logs, or overinflated fire hose can be effective. Very often improvised booms are used ahead of commercial booms to divert debris from damaging the commercial booms. These configurations are particularly valuable in small streams where conventional booms might be ineffective.

DECISION GUIDELINES FOR CONTAINMENT METHODS

Using the information in the preceding section, a guide for applicable containment methods is shown in Table 20.

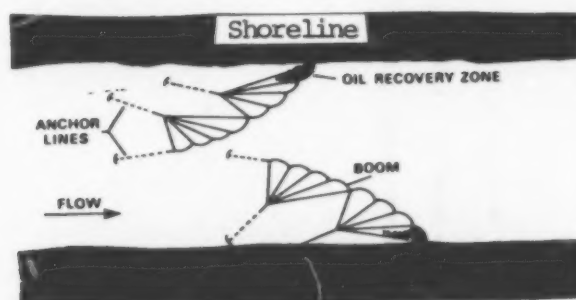


Figure 7. Chevron-shaped deployment.

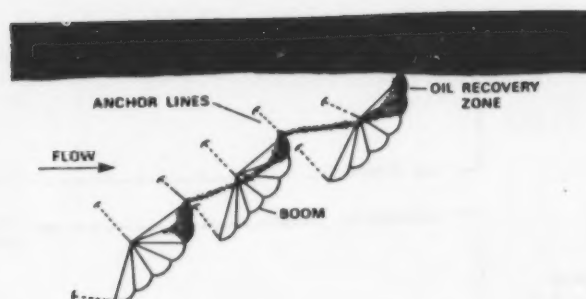


Figure 8. Cascading boom deployment.

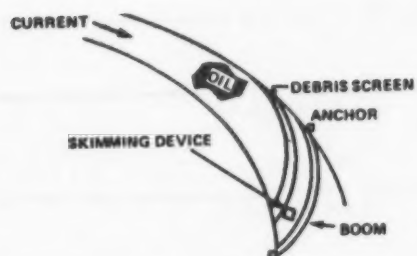


Figure 9. Diagonal deployment.

TABLE 20. DECISION GUIDE FOR CONTAINMENT METHODS (STEP D)

TYPE OF WATER BODY	WAVE CONDITIONS	CURRENT	CONTAINMENT METHOD
Open Water • Inland (Lake, Pond) • Ocean	Low waves (0-0.3 m; 0-1 ft.)	low/moderate current	Class II or III boom Piston film Sorbent barrier
		fast current	Class III boom (V or U shape)
	Moderate waves (0.3-1 m; 1-3 ft.)	low/moderate current	Class III boom Piston film
		fast current	Class III boom
	High waves (1-2.5 m; 3-8 ft.)	low/moderate current	Class III boom
		fast current	Class III boom
Protected Waters • Rivers • Bay • Harbor • Stream • etc.	Low waves (0-0.3 m; 0-1 ft.)	low/moderate current (≤ 0.8 m/s; ≤ 1.5 k)	Airbarrier Exclusion boom Sorbent barrier Piston Film Chemicals Air or water spray
		fast current (< 0.8 m/s; ≤ 1.5 k)	Class II boom
	Moderate waves (0.3-1 m; 1-3 ft.)	low/moderate current (≤ 0.8 m/s; ≤ 1.5 k)	Class II boom
		fast current (< 0.8 m/s; < 1.5 k)	Class II boom

SECTION 8

BEST PRACTICAL PROTECTION METHODS (STEP K)

Area protection from oil contamination is essential for an effective spill response. Once an area is contaminated, it suffers damage not only from the oil, but also from the cleanup methods. Three methods are commonly used to protect sensitive areas: (1) physical devices such as booms, (2) sorbent barriers, and (3) dispersants.

Physical devices are used to protect shorelines from oil contamination. There are two methods for deploying protective barriers: exclusion and diversion.

Exclusion deployment is used to prevent oil from entering an area. An example of this kind of deployment is booming off the entrance to a bay, harbor, or estuary. Diversion deployment is used to move oil from a fast-moving current into calmer waters where it can be contained and cleaned up. With this method some selected areas will be contaminated in order to protect others. Booms are usually deployed at some angle to the current as in the chevron, cascading, or diagonal patterns shown in Figures 7, 8, and 9. Woodward and Clyde, 1979, provides an excellent discussion of protective booming.

Dispersants may be used to protect shorelines, reefs, or natural aquatic resources (such as fishing banks or oyster beds). This is accomplished by applying a dispersant when the slick is sufficiently distant to avoid an effect from either the dispersant or the dispersed emulsified oil. Dispersants may also be applied when a fire or explosion threat exists. Authorization for use of these agents are given in the National Oil and Hazardous Substance Pollution Contingency Plan as follows:

2003 Dispersing Agent Program for Spills of Oil and Applicable Hazardous Substances

2003.1 Authorization for Use of Dispersing Agents

2003.1-1 Major and medium discharges. Dispersing agents may be used in any place, at any time, and in quantities designated by the OSC when their use will:

2003.1-1 1 In the judgment of the OSC, prevent or substantially reduce hazard to human life.

2003.1-1 2 In the judgment of the EPA RRT member on a case-by-case basis, in consultation with appropriate State or Federal agencies, prevent or reduce substantial hazard to a major segment of the population(s) of vulnerable species of waterfowl; or,

2003.1-1.3 In the judgment of the EPA RRT member on a case-by-case basis, in consultation with appropriate State and Federal agencies, result in the least overall environmental damage, or interference with designated water uses.

2003.1-2 Minor discharge. The provisions of section 2003.1-1 shall apply.

2003.2 Special Restrictions on Dispersing Agent Use:

2003.2-1 Chemical agents shall not be considered for use as dispersing agents unless technical product data have been provided and accepted in accordance with 2003.3 except when in the judgment of the OSC the hazards discussed in 2003.1-1.1 are so imminent that the time delay for obtaining a dispersant agent that is in compliance with 2003.3 would be excessive.

2003.2-2 Federal officials responsible for oil and hazardous substance spill response activities at all levels shall develop effective programs to insure that dispersants that are available for use in appropriate spill response actions are dispersants with adequate technical data on file with EPA. This effort will help preclude the avoidance of the EPA technical data program by manufacturers or suppliers who might wish to take advantage of the emergency conditions provision of 2003.2-1.

2003.2-3 For all situations where dispersants are used, accurate records shall be kept on dispersant types, brands, application rates and methods, effectiveness, environmental impacts, plus any other pertinent observations.

The steps involved in making a decision to use dispersants are shown in Figure 10. The information about dispersants should be thoroughly studied prior to a spill incident, and appropriate equipment for application should be available.

Two points are stressed in the decision to use dispersants: (1) their use should result in lower overall environmental damage, and (2) the dispersant should be applied to a dispersible oil. Those oils that can be dispersed are shown in Table 21.

Protection of shorelines and aquatic resources from potential oil contamination is an important step in reducing both environmental impact and cleanup costs. Using the information in this section, a decision guide for protection methods is given in Table 22.

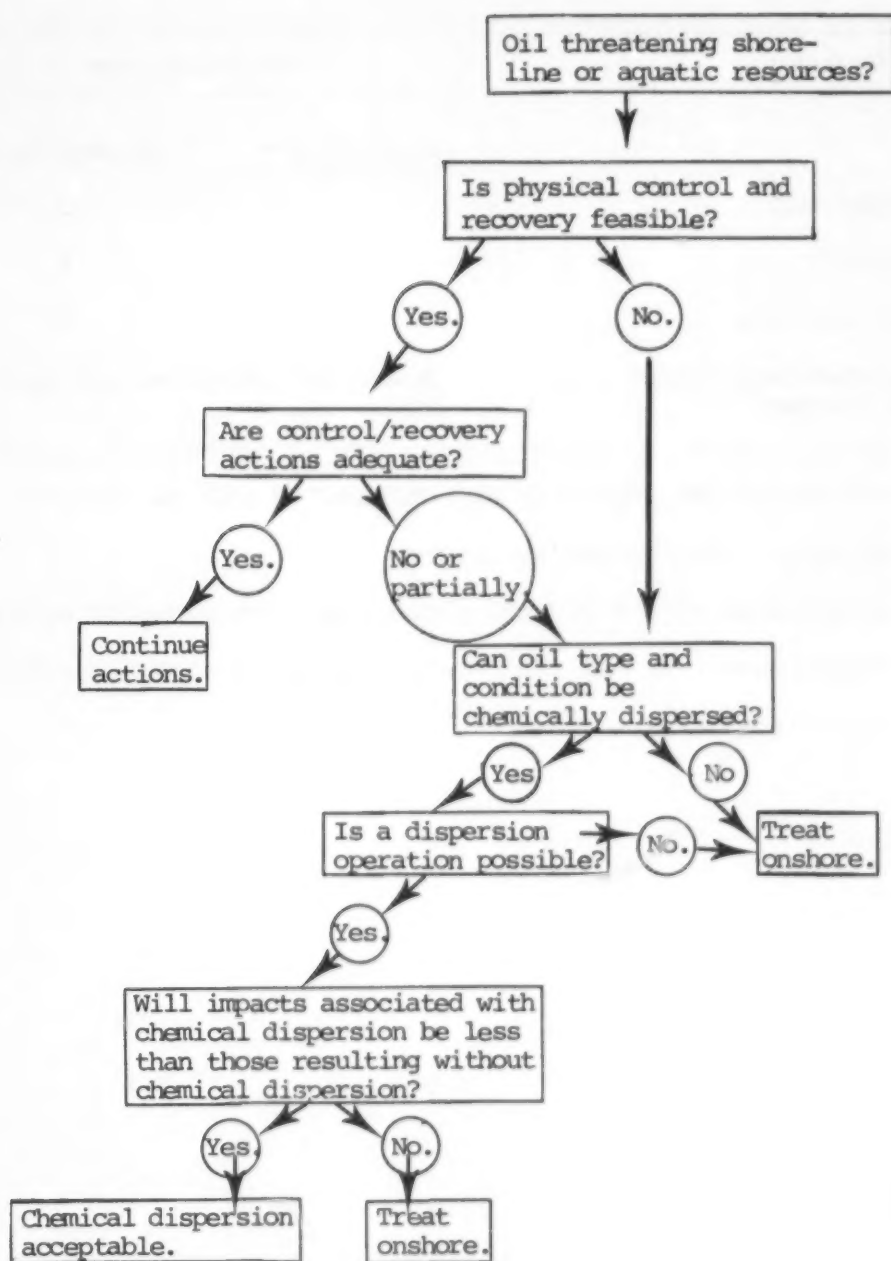


Figure 10. Decision guide for dispersant use.
(Castle and Schrier, 1979)

TABLE 21. GENERAL COMPATIBILITY OF OIL TYPES WITH DISPERSANT TYPES

Oil Category	Dispersant Type	
	<u>Water-Soluble</u>	<u>Solvent-Soluble</u>
Free-flowing oils	1	2
Viscous oils	3	4
Semisolid, tar-like	2	5
Well-developed water-in-oil emulsions (mousse)	Usually NOT effective, not well documented.	

1. NOT RECOMMENDED BECAUSE OF HIGH EVAPORATIVE LOSS AND TOXICITY.
2. Effective under optimal conditions.
3. Effective on oils with lower viscosities (high spreading rates).
4. Effective on oils with high viscosities (lower spreading rates).
5. Effectiveness may be marginal.

TABLE 22. DECISION GUIDE FOR PROTECTION METHODS (STEP K)

TYPE OF WATER BODY	WAVE CONDITIONS	CURRENT	PROTECTION METHOD
Protected Waters • Rivers • Bay • Harbor • Stream • Etc.	low waves (0-0.3 m; 0-1 ft)	low/moderate current (< 0.8 m/s; $< 1.5k$)	exclusion boom sorbent boom or barriers air barriers surface collecting agents
		fast current (> 0.8 m/sec; $> 1.5k$)	diversion boom
	moderate waves (0.3-1 m; 1-3 ft)	low/moderate current (< 0.8 m/s; $< 1.5k$)	diversion boom exclusion boom
		fast current (> 0.8 m/s; $> 1.5k$)	diversion boom
Open Water • Inland (Lake, Pond) • Ocean	low waves (0-0.3 m; 0-1 ft)	low/moderate current	exclusion boom sorbent boom diversion boom surface collecting agents
		fast current	diversion boom
	moderate waves (0.3-1 m; 1-3 ft)	low/moderate current	diversion boom dispersants (ocean only)
		fast current	diversion boom
	high waves (1-2.5 m; 3-8 ft)	low/moderate current	diversion boom dispersants (ocean only)
		fast current	diversion boom

SECTION 9

BEST PRACTICAL RECOVERY AND REMOVAL METHODS (STEP S)

METHODS FOR OIL RECOVERY AND REMOVAL ON WATER

Once an oil spill is contained and sensitive areas are protected, the recovery process begins. Usually the containment methods can also be applied to recovery efforts. This takes advantage of the increased thickness of the oil and containment barrier integrity. The basic methods for recovery and removal of oil on water are as follows:

- natural processes -- evaporation, emulsification, biodegradation
- burning
- fostered biodegradation
- chemical agents for dispersion
- physical methods -- manual or mechanical collection

Natural Processes

Very often, bad weather and rough sea conditions cause natural processes such as evaporation, emulsification, sinking, and biodegradation to occur before containment and recovery operations can begin. In cases where no threat occurs to land or natural aquatic resources, an OSC may decide not to clean up an oil slick on water.

Burning

Burning can be accomplished successfully if the oil is sufficiently thick. This may not be an acceptable method unless there is a direct threat to human life and property, because burning may degrade air quality and produce potentially toxic airborne and water-soluble residues.

Fostered Biodegradation

Biodegradation of oil spills occurs naturally, since many microorganisms have a large capacity to utilize petroleum hydrocarbons as an energy source. Man-induced acceleration of such processes have been studied for use as a cleanup technique. There are four limiting factors for successful fostered biodegradation: (1) the chemical composition of the oil itself, (2) the water

temperature, (3) the addition of the optimum mineral nutrients (N, P, Fe), and (4) the proper contact time between the microorganisms, mineral nutrients, and oil slick.

For these reasons, most large-scale fostered biodegradation methods are too slow to be used as a means to completely remove oil slicks from open waters, or from areas in imminent danger from an oil slick. Therefore, it is generally not a recommended practice, but can be used as a small-scale final polishing action in enclosed waters. It is also expensive, and there is a question as to whether it is an environmentally beneficial action, since it can cause localized eutrophic conditions.

Chemical Agents for Dispersion

Dispersion agents do not really remove oil. They spread the spill and reduce the oil's visibility. While the use of these agents is discouraged, EPA may authorize them to reduce a fire or explosion hazard. An example of such an emergency is a fresh spill of free-flowing oil endangering personnel safety and property which could be dispersed by a less toxic, water-based agent. However, caution is advised in spills of volatile oils where both the application and subsequent agitation may actually increase fire hazards. Furthermore, it should be realized that in spills of volatile oils (e.g., No. 1 to No. 4 fuel oils), natural agitation by winds, waves and currents may rapidly disperse the oil. The more toxic, petroleum-based dispersants are effective in removing weathered oil from equipment.

Physical Methods

Physical methods such as manual and mechanical collection procedures include:

- skimmers
- sorbents
- manual removal

During an oil spill incident, it is possible to use all of these.

Skimmers--

Skimmers are divided into three sizes by the U.S. Navy:

- small -- unmanned, deployable by two men
- medium -- unmanned, trailer-mounted, deployable using an air-driven winch and jib boom
- large -- manned, self-propelled

Independent of size, the operational principles of common commercial skimmers are outlined in Table 23.

TABLE 23. SUMMARY OF SKIMMERS

TYPE OF SYSTEM	PRINCIPLE OF OPERATION	ADVANTAGES	DISADVANTAGES	APPLICATION
Centrifugal	Suction: This unit operates by creating a water vortex, or whirlpool, which draws the oil into the collection area.	Not as susceptible to clogging with debris.	Ineffective in currents exceeding 30 cm/sec (0.6 knots) and waves higher than 60 cm (2 ft).	Calm waters.
Suction	Suction: This skimmer floats at oil-water interface and generally uses an external vacuum pump system.	High capacity. Compact. Shallow draft. Simple to operate. Covers a wide range of oil viscosity.	Easily clogged by debris. Susceptible to wave action. Loss of suction in currents exceeding 30 cm/sec (0.6 knots) because of a tendency to plane over water surface.	Calm waters. Shallow water or confined areas.
Rotating Nonporous Belt	Oleophilic movement along inclined plane: The skimmer forward motion or the water current brings the oil slick in contact with the rotating, smooth-surfaced conveyor belt. The combined action of the rotating belt and the relative water velocity causes oil to be dropped below the surface of the water. At the bottom roller, the oil leaves the belt and rises to the surface of the calm water region inside the collection well.	Skimming principle not affected by oil viscosity. Most efficient of all the seven types here. Can be used in most water conditions. Not hampered by debris.	Requires slow movement over water surface to prevent oil from missing collection well. Generally large; cannot be used in confined areas.	Useful in all types of oil, especially low-specific-gravity oils. Can be used in both rough and calm waters.
Hydro-Adjustable Overflow Weir	Suction: The weir depth (d) of this skimmer can be controlled by varying the pumping rate out of the skimmer. In thick slicks the pumping rate is increased, and the fluid inside the device does not have a chance to fill the rear buoyancy chamber. This results in a buoyancy force which lowers the front weir deeper into the water. Conversely, in thin slicks a slower pumping rate allows the rear buoyancy chamber to fill, weighting the rear of the device to lift the front weir closer to the water surface. A debris screen is placed over the frontal weir opening. The device is not very effective when skimming viscous oils, which tend to clog the front debris screen or the narrow sloping passage leading to the rear buoyancy chamber.	High capacity.	Not very effective in skimming viscous oils. Susceptible to wave action. Easily clogged by debris.	Works best in calm, debris-free waters with thick oil slick.

(Continued)

TABLE 23 (CONTINUED)

TYPE OF SYSTEM	PRINCIPLE OF OPERATION	ADVANTAGES	DISADVANTAGES	APPLICATION
Simple Overflow Weir	Gravity: A simple overflow weir is floated on the surface and its weir depth adjusted to just skim the (usually) thin oil slick. The shallow weir depth must be manually changed by adding or removing weights, or moving attached floats up and down.	Simple device. Shallow draft. Good mobility.	This device is inefficient in waves. As the weir opening becomes flooded with water, oil is carried above the weir opening. Easily clogged by debris.	Works best in calm debris-free water with thick oil slicks.
Advancing Weir	Gravity: The velocity of the oil and water flowing into the unit over the front weir is reduced during its flow over the sloping floor to the device, allowing oil to separate, by gravity, to the top. A hinged door in the floor of the device allows water to pass out, while a mechanically operated weir is used to skim settled oil into the collection box.	Simple device. Easy mobility.	The rear overflow weir is difficult to adjust. Large quantities of water are taken into the collection box. Waves flood the overflow weir, causing oil droplets to form and be carried out the bottom door.	Calm, debris-free water.
Double Advancing Weir	Gravity: This unit operates similarly to the advancing weir principle except that a leading float serves to absorb a large portion of the incoming wave energy, thereby providing a relatively calm water region for gravity separation of the oil. The outlet of a pump is placed near the waterline to skim the separated oil. Water flowing into the device exits through a fixed opening in the bottom of the device.	Simple device. Easy mobility.	Draze too much water. Debris reduces efficiency. Susceptible to wave action.	Calm, debris-free water.
Oleophilic Rope-Type	Adhesion.	Most efficient with medium viscosity oil. Less vulnerable to wave action.	Retracting action can cause turbulence (pressure waves) which may drive oil from skimmer.	Thick slick of viscous oil.

Sorbents--

Sorbents act through the process of adsorption or absorption and remove small quantities of oil. Sorbents are either (1) natural materials, such as peat moss and straw, (2) mineral-based materials, such as vermiculite and volcanic ash, or (3) synthetic materials, such as polyester foam, polyurethane, and polystyrene. The advantages and disadvantages of sorbents are summarized in Table 24.

Manual Removal--

Manual removal of oil is used for small spills involving viscous or semi-solid oil. This procedure involves a labor-intensive effort using equipment such as buckets, rakes, and shovels. Manual removal of free-flowing oil is usually not very successful. Better results are obtained when sorbents are used on this type of oil.

Decision Guide for Water Cleanup Methods

The decision guide (Table 25) indicates the applicability of each method according to type of waterbody and environmental conditions. Very often the choice of method will depend upon the availability of appropriate equipment. When there is a choice between using two appropriate methods, the effectiveness of each cleanup rating system should be evaluated.

METHODS FOR OIL RECOVERY AND REMOVAL ON SHORELINES

Cleanup of oil stranded on shorelines is not subject to the same time constraints as those governing offshore oil spill cleanup. It is possible, therefore, to give more attention to specifics including environmental factors, cleanup techniques, equipment, and manpower. However, this does not imply that work should proceed with undue caution; rather, cleanup procedures should be efficiently organized and implemented in a rapid but orderly manner to minimize oil migration and additional environmental damage.

Each cleanup activity must be adapted to individual shoreline characteristics and these are listed below in order from least to most sensitive:

- exposed rocky headlands
- unresistant, unconsolidated cliffs or banks
- flat, fine-grained sand beaches
- steeper, coarse-grained sand beaches
- exposed, fine-grained mud or sand compacted tidal flats
- mixed sand and gravel beaches
- gravel beaches
- coral reef
- sheltered rocky coasts
- sheltered tidal flats
- marshes and mangroves

TABLE 24. SUMMARY OF SORBENT MATERIALS

TYPE	ADVANTAGES	DISADVANTAGES	EXAMPLE	OIL CAPACITY*
Natural Sorbents	Non-toxic materials. Will biodegrade.	Soak both oil and water and will sink when saturated. Recovery of large amounts of sorbent is a labor-intensive operation. Trapped oil may drain off material.	Peat moss. Straw. Milled corn cobs. Wood cellulose fiber. Milled cottonseed fiber.	In general, absorb 3-6 times their weight in oil.
Inorganic or Mineral-Based Sorbents		Very light materials and are difficult to distribute when windy. Will not degrade (non-biodegradable). Dust may cause respiratory irritations. Can be abrasive to recovery equipment.	Perlite. Vermiculite. Volcanic ash.	In general, absorb 4 to 8 times their weight in oil.
Synthetic Sorbents	Exceptionally high recovery efficiencies. Some materials can be re-used after oil removal. Easily spread. Easily recovered. Available in many forms (rolls, sheets, booms).	Expensive. Non-biodegradable.	Polyurethane. Urea formaldehyde. Polyethylene. Polypropylene.	Variable, but higher than non-synthetic solvents.
Synthetic Foam Sorbents	Most efficient sorbents available. Efficiency independent of oil viscosity. Can produce material at site by mixing two liquids.	Oil-saturated slabs may tear during recovery.	Polyurethane foam.	

* More specific capacities may be found on table in Appendix E.

TABLE 25. DECISION GUIDE FOR WATER CLEANUP METHODS (STEP U)

TYPE OF WATER BODY	WAVE CONDITIONS	CURRENT	CLEANUP METHOD
Protected Waters • Rivers • Bay • Harbor • Stream • Etc.	Low waves (0-0.3 m; 0-1 ft)	Low/moderate current (<0.8 m/s; <1.5 k)	Physical methods - manual or mechanical Natural processes Foisted biodegradation
		Fast current (>0.8 m/s; >1.5 k)	Physical methods - manual or mechanical Natural processes
	Moderate waves (0.3-1 m; 1-3 ft)	Low/moderate current (<0.8 m/s; <1.5 k)	Physical methods - manual or mechanical Natural processes
		Fast current (>0.8 m/s; >1.5 k)	Natural processes Physical methods - manual or mechanical
Open Water • Inland (Lake, Pond) • Ocean	Low waves (0-0.3 m; 0-1 ft)	Low/moderate current	Physical methods Natural processes Burning
		Fast current	Physical methods - manual or mechanical Natural processes
	Moderate waves (0.3-1 m; 1-3 ft)	Low/moderate current	Physical methods - manual or mechanical Natural processes Dispersants (ocean only)
		Fast current	Physical methods - manual or mechanical Natural processes Dispersants (ocean only)
	High waves (1-2.5 m; 3-8 ft)	Low/moderate current	Natural processes Dispersants (ocean only)
		Fast current	Natural processes Dispersants (ocean only)

In addition to the natural components, man-made structures must be considered. These include piers, boat ramps, seawalls, oil-handling facilities, recreational areas, and homes. Structures are not confined to any single shoreline, but may be located anywhere. There are three basic types of structures: (1) concrete structures for which rock surface cleanup methods are used, (2) rock or broken concrete structures for which gravel cleanup methods are used, and (3) wood piling structures for which there are no analogous natural characteristics. These structures must be handled as special cases.

There are several methods applicable for shoreline cleanup. These techniques are summarized in Table 26.

- natural processes
- burning
- physical removal
 - manual
 - light mechanical
 - heavy mechanical
- chemical removal
- biological agents

Several factors must be considered prior to selection of the most appropriate technique for cleaning the shoreline. First, the cleanup technique must conform to the shoreline geomorphology and the characteristics of the oil. Included are such variables as access to the site, types of substrates, and degree of contamination. The techniques applicable to each shoreline type are found in Table 27. Second, the disadvantages of possible techniques must be assessed. Included are such variables as effects on shoreline erosion rates, disruption of organism habitats, and time required for organism rejuvenation after cleanup is completed. These impacts can be found in Table 28.

All cleanup and recovery techniques affect the substrate. The effects may result from forcing oil into the substrate by walking or moving equipment over an area or from removing organisms or substrate surface. These actions can cause more damage to the environment and the biota than the oil. The OSC must use judgment in determining if physical cleanup actions for an oiled area are necessary. Several guidelines are given here and on the decision guide in Figure 11.

- In high energy environments, natural cleaning will be most effective.
- In marshes, natural cleaning eliminates the possible damage caused by tramping oil into the substrate which can destroy the root integrity of the marsh. If marshes are to be cleaned, several viable options are advocated: (1) burning during the late fall - early spring, or (2) cutting and removing contaminated foliage by boat.

TABLE 26. SUMMARY OF SHORELINE CLEANUP TECHNIQUES
Source: Woodward and Clyde, 1978.

Method	No.	Technique	Description	Advantages	Disadvantages	Application	Rate of Removal
Natural Processes	1	Natural recovery.	No action taken - oil left to degrade naturally.	No additional effects on the environment because of cleanup activity. Will remove all oil. No manpower or equipment requirements.	Some oil may be left on the beach to contaminate other areas. Potential incorporation of oil into the food web. Elimination of habitat for organisms.	High energy beaches of cobble, gravel, boulder, or rock where wave action will clean contaminant rapidly.	Slow
Burning	2	Controlled burning.	Upwind end of contaminated area is ignited and allowed to burn downwind.	Rapid removal of a majority of contaminant. Not very labor-intensive.	Can cause damage to vegetation and air pollution; can lead to erosion if root system of vegetation is harmed. Extensive heat kills shallow burrowing organisms. Heavy metal residual matter may be toxic.	Coastal and inland vegetation and substrate with sufficient oil of light volatiles to sustain combustion.	Fast
Chemical Removal	3	Gelling or coagulation.	Addition of agent would remove the oil from the land surface. Agents applied to the oil forming a semi-rigid mass which aids oil removal.	Easy to apply to inaccessible areas. Will remove most of the oil.	Expensive to apply. Possible toxic effects to soil organisms. Use must be carefully controlled.	Coastal and inland beaches, gravel shorelines, and man-made structures.	Moderate
Biological Agents	4	Forced biodegradation.	Addition of microbial organisms to the oil-contaminated areas to facilitate biological removal of the oil. Addition of nutrients to hasten biological activity.	Easy to apply and does not harm the aquatic environment.	Hard to regulate and produce desired results under field conditions. Variable success. Expensive. Optimum growth condition required.	Low energy shorelines with substrate suitable for microbial growth such as coarse sand.	Slow
Physical Removal: A. Manual	5	Manual scraping.	Oil is scraped from substrate using hand tools.	Selective removal of material. Most oil can be removed if effort is sufficient.	Removes or crushes organisms and oil not removed can be toxic to organisms repopulating the areas. Labor-intensive.	Foot access. Used on lightly contaminated boulders, rocks, or man-made structures.	Moderate

(continued)

TABLE 26 (CONTINUED)

Method	No.	Technique	Description	Advantages	Disadvantages	Application	Rate of Removal
Physical Removal: A. Manual	6	Manual removal of oiled materials.	Oil sediments and debris are removed by: hand, shovel, rake, wheelbarrow.	Rapid recovery because only selected areas are disturbed.	Removes some shallow burrowing animals. Small amount of sediment disturbance and erosion. Labor-intensive.	Foot or light vehicle access. Used on beaches of sand, gravel, and cobble when oil contamination and penetration is light or where heavy equipment access is impossible.	Moderate
	7	Manual cutting.	Oiled vegetation is cut by hand, and collected for disposal.	Rapid recovery in most environments.	Disturbs sediments because of foot traffic and causes erosion. Foot traffic can also crush organisms and disturb nesting of birds. Labor-intensive.	Foot access. Used to remove oil from marsh lands (wetlands) vegetation.	Moderate
	8	Manual sorbent.	Sorbents applied manually to soak up oil in contaminated areas.	Selective areas for removal of contaminant.	Foot traffic may crush organisms. Ingestion of sorbents by birds or small mammals. Labor-intensive.	Foot access. Used to remove light, non-sticky oil from mud, boulders, rocks, and man-made structures.	Moderate
B. Light Mechanical	9	Low-pressure flushing.	Application of low-pressure water spray flushes oil and directs it to collection area.	Does not disturb sediments or organisms to any great extent.	Potential for recontamination or contamination of areas downlope. Moderate labor requirements.	Light vehicles access. Used on lightly contaminated mud, cobbles, boulders, roads, man-made structures, or in contaminated marsh lands (wetlands).	Past
	10	High-pressure flushing.	Application of high-pressure water stream to remove oil.	Most efficient method for cleaning boulders, rocks, and man-made structures.	Can disturb surface of substrate. Oil not recovered may be toxic to organisms downlope. Removes some organisms and shells from surface. Moderate labor requirements.	Light vehicular access and a supply of fresh or salt water. Cleans boulders, rocks, and man-made structures. Is used for light to extensive contamination.	Past

(continued)

TABLE 26 (CONTINUED)

Method	No.	Technique	Description	Advantages	Disadvantages	Application	Rate of Removal
Physical Removal: B. Light Mechanical	11	Steam cleaning.	Application of steam to remove oil contamination.	Empty shells remain and enhance repopulation.	Adds heat to the surface and removes or kills organisms on surface. Oil not recovered may be toxic to organisms downstream. Moderate labor requirements.	Light vehicular access and a supply of fresh water. Cleans boulders, rocks, and man-made structures. Is used for light to extensive contamination. Not recommended for surfaces supporting life.	Fast
	12	Sand blasting.	Removal of oil from contaminated surfaces by high-velocity sand.	Fast and efficient removal. Moderate labor requirements.	Removes all organisms and sediments to environment. Oil residues not collected may be toxic to organisms downstream.	Light vehicular access. Cleans residues from man-made structures. Used only when oil is a thin coating and no alternative method.	Fast
	13	Oil skimmers.	Use of skimming devices to remove oil from small water pockets.	Refer to Table 24.			
	14	Vacuum pumping.	Removal of oil pools by use of vacuum equipment.	Does not disturb organisms outside the trench line or sump area. Low labor requirements.	Effective only for thick pockets of oil; does not remove oil completely.	Heavy equipment access and a longshore current present. Firm sand beaches or mud and on river or streams with a boom diversion.	Fast
C. Heavy Mechanical	15	Backhoe.	Removal of contaminated sediments and loads them into truck for disposal.	Can reach areas inaccessible by other heavy equipment. Low labor requirements.	Removes all organisms; rehabilitation of the area is slow; creates severe reduction of bank or beach stability. Slow cleaning rate.	Heavy equipment access to stable working area. Banks and narrow beaches. Primarily mud and silt removal.	Moderate
	16	Dragline.	Removal of contaminated ground by dragging a bucket across the contaminated surface while the equipment is on stable ground.	Can reach areas inaccessible by other heavy equipment. Greater reach than backhoe. Low labor requirements.	Removes all organisms and rehabilitation of the area is slow. Creates severe reduction of bank or beach stability.	Heavy equipment access to stable working area. Contamination of river banks and narrow beaches. Sand, gravel, mud and cobble removal.	Moderate

(continued)

TABLE 26 (CONTINUED)

Method	No.	Technique	Description	Advantages	Disadvantages	Application	Rate of Removal
Physical Removal:							
C. Heavy Mechanical	17	Beach cleaner.	Picks up tar balls or oil patties; either self-propelled or pulled by tractor.	Good trafficability and rapid cleanup. Low labor requirements.	Disturbs shallow burrowing organisms.	Moderate to heavy vehicular access. Used on sand and gravel beaches. Lightly contaminated with oil in the form of hard patties or tar balls.	Moderate
	18	Elevating scraper.	Scraper picks up contaminated material directly.	Rapid removal of contaminant. Works on beaches with low bearing capacity. All contaminant removed. Low labor requirement.	Removes both shallow and deep burrowing organisms. Creates very unstable substrate. Recolonization slow. Erosion and beach retreat.	Heavy equipment access. Sand and gravel beaches and some mud flats. 0-3 cm of oil penetration.	Fast
	19	Elevating scraper and motor grader.	Motor grader forms windrows for picking up elevating scraper.	Removes only upper 3 cm of beach. Recolonization of animals rapid. Good trafficability and effective removal of oil. Low labor requirements.	Removes shallow burrowing animals (organisms).	Heavy equipment access. Sand and gravel beaches and some mud flats. 0-3 cm of oil penetration.	Moderate
	20	Front-end loader with rubber tires or tracks.	Front-end loader picks up material directly off beach and hauls to unloosed area for disposal.	Excellent for removal of contaminated cobbles. Low labor requirements.	Removes 10 to 20 cm of beach. Causes severe reduction in beach stability. Removes all shallow and deep burrowing organisms.	Heavy equipment access. Mud, sand, or gravel beaches. Oil penetration moderate to light. Useful in removal of contaminated beach vegetation.	Moderate
	21	Front-end loader and motor grader.	Motor grader forms windrows of contaminated matter for pickup by front-end loader.	Removes only upper 3 cm of beach. Recolonization of animals rapid. Effective removal of oil. Low labor requirements.	Removes shallow burrowing organisms. Cleanup rates are not extremely fast.	Heavy equipment access. Sand and gravel beaches. 2-3 cm of oil penetration.	Moderate
	22	Front-end loader and bulldozer.	Bulldozer pushes contaminated ground into piles for pickup by front-end loader.	Works well in areas of poor trafficability. Low labor requirements.	Removes all organisms. Removes 15-50 cm of sediment. Severe erosion and cliff or beach retreat.	Heavy equipment access. Used on coarse sand, gravel, or cobble beaches. Oil penetration is deep. Removal of heavily oil-contaminated vegetation.	Moderate

(continued)

TABLE 26 (CONTINUED)

Method	No.	Technique	Description	Advantages	Disadvantages	Application	Rate of Removal
Physical Removal: C. Heavy Mechanical	23	Tractor breaking up pavement.	Tractor fitted with ripper for use on heavy contamination.	Reduces beach erosion by not removing sediment. Low labor requirements.	Disturbs shallow and deep burrowing organisms and the beach sediments. Leaves oil on the beach.	Heavy equipment access. Thick oil layer has formed a pavement. Used on high energy beaches of cobble, gravel, or sand where removal of sediment would cause severe beach erosion. Used on low priority beaches.	Moderate
	24	Push contaminated substrate into surf zone.	Bulldozer pushes contaminated substrate into surf zone to accelerate cleaning.	Recovery more rapid than total removal of substrate. Low labor requirements.	Causes erosion of the back shore area. Kills most organisms of the contaminated zone.	Heavy equipment access. High energy shoreline of sand, gravel, or cobble.	Fast
	25	Disc contaminant into substrate.	Tractor discing equipment along contaminated substrate (light contamination).	Reduces beach erosion by not removing sediment. Low labor requirements.	Leaves oil on the beach and disturbs burrowing organisms.	Heavy equipment access. Used on non-recreational high energy beaches, sand and gravel beaches that are lightly contaminated.	Fast

TABLE 27. DECISION GUIDE OF APPLICABLE SHORELINE CLEANUP AND RECOVERY TECHNIQUES

	Sand Beach				Wetlands										Man Made Structures			
	Exposed Rocky Headlands	Unconsolidated Cliffs or Bank	Flat, Fine Grained	Steeper, Coarse Grained	Exposed Tidal Flat	Sand/Gravel Beaches	Gravel Beaches	Coral Reef	Sheltered Rocky Coasts	Sheltered Tidal Flats	Marsh	Mangrove Swamp	Concrete	Rock or Broken Concrete	Wood			
1. Natural Process	✓	✓	+	✓	✓	✓	✓	✓	+	✓	✓	✓	+	+	+			
2. Burning	0	0	NR	NR	NR	NR	NR	0	0	0	+	+	0	0	0			
3. Chemical Agents	+	0	+	+	+	+	+	NR	+	+	+	+	+	+	+			
4. Biological Agents	0	0	+	+	0	+	0	0	0	0	+	+	0	0	0			
5. Manual Scraping	+	NR	+	+	+	✓	✓	+	✓	+	+	+	+	0	+			
6. Manual Removal	✓	+	✓	✓	+	✓	✓	+	✓	+	+	+	✓	✓	✓			
7. Manual Cutting	0	0	0	0	0	0	0	0	0	0	+	NR	0	0	0			
8. Manual Sorbent	+	+	✓	✓	+	✓	+	+	+	+	+	+	+	+	+			
9. Low Pressure Flushing	✓	NR	NR	+	+	+	+	+	✓	+	+	+	✓	+	✓			
10. High Pressure Flushing	+	NR	NR	NR	NR	NR	+	0	+	NR	NR	NR	+	+	✓			
11. Steam Cleaning	+	NR	NR	NR	NR	NR	NR	0	+	NR	NR	NR	+	NR	+			
12. Sandblasting	+	NR	NR	NR	NR	NR	NR	0	+	NR	NR	NR	+	NR	+			
13. Oil Shimmers	0	NR	+	+	+	+	+	+	+	NR	+	+	0	0	0			
14. Vacuum Pumping	0	NR	NR	NR	NR	NR	+	+	+	+	NR	NR	0	0	0			
15. Backhoe	0	NR	+	+	NR	+	+	0	0	NR	NR	NR	0	0	0			

✓ = Recommended

+ = Useful in some instances

NR = Not recommended

0 = Not applicable

TABLE 27 (CONTINUED)

	Sand Beach				Wetlands								Man Made Structures			
	Exposed Rocky Headlands	Unconsolidated Cliffs or Bank	Flat, Fine Grained	Steeper, Coarse Grained	Exposed Tidal Flat	Sand/Gravel Beaches	Gravel Beaches	Coral Reef	Sheltered Rocky Coasts	Sheltered Tidal Flats	Marsh	Mangrove Swamp	Concrete	Rock or Broken Concrete	Wood	
16. Dragline	0	NR	+	+	NR	+	+	0	0	NR	NR	NR	0	0	0	
17. Beach	0	NR	+	+	NR	+	+	0	0	NR	NR	NR	0	0	0	
18. Clearing	0	NR	+	+	NR	+	+	0	0	NR	NR	NR	0	0	0	
19. Elevating Scraper	0	NR	+	+	NR	+	+	0	0	NR	NR	NR	0	0	0	
19. Elevating Scraper & Motor Grader	0	NR	+	+	NR	+	+	0	0	NR	NR	NR	0	0	0	
20. Front End Loader	0	NR	+	+	NR	+	+	0	0	NR	NR	NR	0	0	0	
21. Front End Loader & Motor Grader	0	NR	+	+	NR	+	+	0	0	NR	NR	NR	0	0	0	
22. Front End Loader & Bulldozer	0	NR	+	+	NR	+	+	0	0	NR	NR	NR	0	0	0	
23. Tractor	0	NR	+	+	NR	+	+	0	0	NR	NR	NR	0	0	0	
24. Bulldozer Push Oil Into Surf	0	NR	+	+	NR	+	+	0	0	NR	NR	NR	0	0	0	
25. Ditching	0	NR	+	+	NR	+	NR	0	0	NR	NR	NR	0	0	0	

/ = Recommended

+ = Useful in some instances

NR = Not recommended

0 = Not applicable

TABLE 28. IMPACTS OF CLEANUP AND RECOVERY TECHNIQUES

Method	No.	Technique	Physical Removal of Substrate • none = <0.5 cm • slight = 0.5-3 cm • moderate = 3-10 cm • great = 10-25 cm • severe = >25 cm	Erosion Potential • none • slight • moderate • severe	Organisms Removal • surface • shallow = <5 cm • deep = >5 cm • toxic	Expected Recovery Rate of Area • fast = <6 mos. • slow = 6-24 mos. • very slow = >24 mos.
Natural Process	1	Natural recovery (no action)	None	Slight	None	Very slow
Burning	2	Controlled burning	None	Moderate	Shallow, <5cm	Slow
Chemical Removal	3	Dispersion, sinking, gelling, or coagulation	None	None	Possibly toxic to organisms	Fast
Biological Agents	4	Addition of microbial populations	None	None	None	Slow
Physical Removal						
A. Manual	5	Manual scraping	Slight	Slight	Surface	Slow
	6	Manual removal of oiled materials	Slight	Moderate	Shallow	Fast
	7	Manual cutting	None	Severe	Surface	Fast
	8	Manual sorbent	None	Slight	Surface	Slow

(continued)

TABLE 28 (CONTINUED)

Method	No.	Technique	Physical Removal of Substrate • none = <0.5 cm • slight = 0.5-3 cm • moderate = 3-10 cm • great = 10-25 cm • severe = >25 cm	Erosion Potential • none • slight • moderate • severe	Organisms Removal • surface • shallow = <5 cm • deep = >5 cm • toxic	Expected Recovery Rate of Area • fast = <6 mos. • slow = 6-24 mos. • very slow = >24 mos.
Physical Removal						
B. Light Mechanical						
	9	Low pressure flushing	Slight	Slight	Surface	Fast
	10	High pressure flushing	Moderate	Moderate	Shallow	Fast
	11	Steam cleaning	None	Moderate	Surface	Slow
	12	Sandblasting	Slight	Moderate	Surface	Slow
	13	Oil skimmers	None	None	None	Fast
Physical Removal						
C. Heavy Mechanical						
	14	Vacuum pumping	None	Moderate	Surface	Slow
	15	Rackho	Severe	Severe	Deep	Slow
	16	Dragline	Severe	Moderate	Deep	Very slow
	17	Beach cleaner	Great	Moderate	Shallow	Slow

(continued)

TABLE 28 (CONTINUED)

Method	No.	Technique	Physical Removal of Substrate • none = <0.5 cm • slight = 0.5-3 cm • moderate = 3-10 cm • great = 10-25 cm • severe = >25 cm	Erosion Potential • none • slight • moderate • severe	Organisms Removal • surface • shallow = <5 cm • deep = >5 cm • toxic	Expected Recovery Rate of Area • fast = 6 mos. • slow = 6-24 mos. • very slow = >24 mos.
Physical Removal C. Heavy Mechanical	18	Elevating scraper	Slight	Moderate	Shallow	Slow
	19	Elevating scraper and motor grader	Slight	Moderate	Shallow	Slow
	20	Front-end loader with rubber tires	Moderate	Severe	Deep	Very slow
	21	Front-end loader and motor grader	Slight	Moderate	Shallow	Slow
	22	Front-end loader and bulldozer	Severe	Severe	Deep	Very slow
	23	Tractor breaking up pavement	Moderate	Moderate	Shallow	Slow
	24	Push contaminated substrate into water	Slight	Moderate	Surface	Fast
	25	Disc contaminant into substrate	None	Moderate	Shallow	Slow

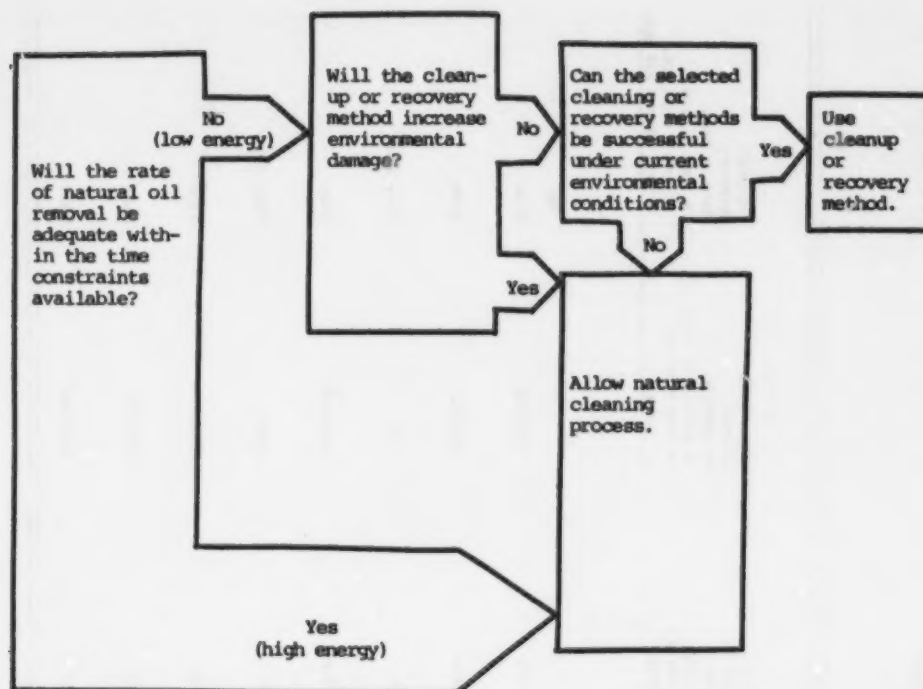


Figure 11. Decision guide for natural cleanup processes.

- In areas with active coastal processes, natural cleaning allows sand to be deposited on top of the oil. In these areas, removal of oiled substrate can result in severe coastal erosion problems.

GUIDELINES FOR SELECTING BEST METHOD FOR CLEANUP AND REMOVAL

The rating system described in Table 29 can be used as an aid in selecting the most effective available cleanup technique(s) for a particular sensitive area. Each cleanup technique can be rated in relation to eight specific criteria. For each technique the ratings can be summed to derive an effectiveness index (ranging from 0 to 18). The technique can then be ranked by effectiveness index (where the higher the index, the more effective the cleanup technique). The tables that supply information are referenced and these ratings can be applied to Table 30 for computation. A method that fails to meet needs should be excluded from consideration.

COST EFFECTIVENESS OF CLEANUP METHODS

In situations where the cost of cleanup is particularly important and can be estimated fairly accurately, the procedure described below can be used to determine the most cost-effective cleanup method. A cost effectiveness ratio can be derived for each method. The methods can then be ranked according to this ratio (where the lower the ratio, the more cost effective the cleanup

TABLE 29. CRITERIA FOR COMPARING EFFECTIVENESS OF CLEANUP TECHNIQUES

Criteria	Rating	Reference
1. Completeness of removal:		
- Oil removal capability under given spill and environmental factors.	+4 Capable of removing >80% of oil. +2 Capable of removing 30-80% of oil. 0 Capable of removing <30% of oil.	Table 26
2. Rate of removal:		
- Rate of removal sufficient to minimize effect on sensitive areas and permit effective cleanup before spreading occurs.	+4 Method exceeds needs. +2 Method meets needs. 0 Method fails to meet needs.	Table 26
3. Logistics:		
- Deployment time lag minimal; ease of maneuverability in small areas at spill site.	+2 Method exceeds needs. +1 Method meets needs. 0 Method fails to meet needs.	Table 26
4. Effect on damage potential:		
- Will not increase pollution or hazard potential of spill situation.	+2 Reduces pollution or hazard. +1 No effect on pollution or hazard. 0 Increases pollution or hazard.	Table 28
5. Sensitivity to environmental factors:		
- Must be operable under given wind, temperature, and wave conditions; must not be greatly hampered by floating debris.	+2 Not affected by given environmental factors. +1 Slightly affected by given environmental factors. 0 Greatly affected by given environmental factors.	Table 27
6. Toxicity to aquatic life:		
- Method will not adversely affect aquatic life that has commercial or recreational value.	+1 Does not adversely affect aquatic life. 0 Adversely affects aquatic life.	Table 28
7. Operational requirements:		
- Operational efficiency will not be constrained by quantity or type of manpower and power requirements.	+1 No problems satisfying operational requirements. 0 Problems in satisfying operational requirements.	Table 26
8. Cost (\$) vs. % of spill removed/days		
- Cost must be acceptable in relation to the completeness and rate of removal.	+2 Relatively low cost. +1 Moderate cost. 0 Relatively high cost.	Note (1) and Appendix C.

Note: The cost of cleanup can be roughly estimated using the following steps:

1. Estimate and sum the expected daily costs for labor, equipment, materials, and supplies. (The cleanup cost [Appendix C] can be used as an aid in estimating these costs.)
2. Estimate the expected quantity of oil that can be removed per day. (Quantity can be expressed in either gallons of oil or percent of oil removed.)
3. Divide the estimated daily cost by the expected daily quantity of oil removed. Use this cost ratio to make relative comparisons between methods and assign the cost rating.

TABLE 30. EFFECTIVENESS OF CLEANUP TECHNIQUES*

Criteria	1	2	3	4
1. Completeness of removal				
2. Rate of removal				
3. Logistics				
4. Effect on damage potential				
5. Sensitivity to environmental factors				
6. Toxicity to marine life				
7. Operational requirements				
8. Cost				
Effectiveness index (sum of 1-8)				

* Range 0-18; the higher the index, the more effective the cleanup technique. These methods should be used unless they are not available. Alternative methods should then be employed according to their effectiveness. Unacceptable methods should not be used.

method). For each method, the cost effectiveness ratio can be determined as follows:

- Derive the ratio of cost/quantity of oil removed (as outlined in the preceding section).
- Determine the effectiveness index on the basis of criteria 1 through 7 only. (Do not include criteria 8, cost.)
- Divide the ratio from step 1 by the effectiveness index from step 2. This yields the cost effectiveness ratio, where:

$$\text{Cost effectiveness ratio} = \frac{\text{Cost per quantity of oil removed}}{\text{Effectiveness index}}$$

SECTION 10

IMPLEMENTATION AND EVALUATION OF SELECTED ACTIONS

IMPLEMENTATION OF PROTECTION AND CLEANUP ACTIONS (STEPS L AND T)

After the OSC has (1) established protection priorities, (2) determined the best practical countermeasures available, and (3) overcome the external constraints, the selected protective actions (Step L) should be implemented as quickly as possible in uncontaminated sensitive areas before any cleanup or recovery measures are undertaken.

After all threatened sensitive areas have been adequately protected and the spill dynamics indicate that no additional areas will undergo contamination, the main effort should be the cleaning up of the oil-contaminated areas. This action (Step V) occurs after the OSC has (1) established cleanup priorities, (2) determined best practical methods available, and (3) overcome the external constraints.

Protection and recovery actions, as mandated by the National Oil and Hazardous Substance Pollution Contingency Plan (40 CFR Part 1510.53), require the use of any countermeasure that will restrain the spread of the oil (from the source) and that will mitigate the oil spill's effects. The OSC has the duty and sole responsibility to ensure that all countermeasure actions are selected and are used properly and expeditiously.

REASSESSMENT OF SPILL DYNAMICS (STEP M)

The dynamics of a spill may change at any time during the spill response because of factors such as:

- recurrence of oil spill or increased rate of spillage
- shift in wind speed or direction
- shift in current speed or direction (that is, tidal changes)
- changes in weather (that is, start of precipitation or temperature changes)
- artificial causes of oil dispersion (that is, large ship wakes or dam overflow)

These changes can either occur quickly or be very gradual and subtle. In either case, the OSC must be able to predict their impact upon the total spill

response. Changes could affect the following phases of the spill response:

- change in damage potential of the spill
- order and degree of contamination for protection or cleanup priorities
- addition of more threatened sensitive areas
- modification of protective countermeasures and cleanup methods
- increased or decreased importance of external constraints upon selected actions
- increased or decreased amount of time necessary to mitigate spill

If the OSC decides, using his best judgment, that the spill dynamics are basically unchanged since the onset of the spill, he should proceed to evaluate the effectiveness of the total spill response (Step V). However, if spill dynamics have changed significantly, they should be reassessed and actions modified following the guidelines in Section 3. The effect upon the spill response should then be measured. The effects of changed spill dynamics upon the response phases are outlined in Table 31. These effects are highly site-specific and difficult to generalize; this table shows only the possible effects.

To be effective, changes in the spill dynamics should be monitored and assessed continuously. Changes can occur quickly and the response to these changes must be immediate and sufficient to minimize any possible adverse impacts of the spill.

OVERALL SPILL RESPONSE EVALUATION (STEP U)

After the response has been adjusted to address any changes in the spill dynamics, or after the initial cleanup actions are well under way, the effectiveness of overall mitigation actions must be evaluated. Effectiveness can be measured by applying the questions below to the total spill response.

- How long did it take after the initial report until arrival on scene?
- Is the source of the oil stopped?
- Is there a potential for spillage from the source because of the oil containment method?
- Have all potentially sensitive areas been identified and protected to the maximum extent possible?
- Have all sensitive areas affected been assessed, and have the best practical recovery and cleanup measures been applied to them?
- Has available manpower and equipment been used effectively and with no waste of time or duplication of effort?

TABLE 31. POTENTIAL EFFECTS OF SPILL DYNAMIC CHANGES ON RESPONSE PHASES

Spill Dynamics Changes	Sensitive Areas	Relative Sensitivity Rating	Protection Priorities	Cleanup Priorities	Protective Actions	Cleanup Actions
Additional Oil Spilled	0	0	0	+	+	+
Increased Movement	+	0	+	0	+	0
Directional Changes	+	0	+	0	+	0
Weathering Changes	0	+	0	+	0	+
Meteorological Changes	+	+	+	+	+	+

+ = some possible significant effect

0 = no significant effect

- Has the public been kept informed, and have the actions selected considered their concerns?

These criteria can be numerically rated, if desired, by using the following determinations of very effective (+3), minimally effective (0), and not effective (-3). Any values between (+3) and (-3) can be assigned to a criterion when the response is between these extremes. To find the total effectiveness values, simply add all eight criteria and compare the relative value (range -24 to +24). The higher the number (+ or -), the more extreme the response. Table 32 illustrates these criteria and their ratings.

If any criterion rates extremely low (-3), the OSC should ascertain why the response was inadequate within this phase and determine the reason (his fault or an uncontrollable outside factor). He should attempt to correct the situation by one or more of the following:

- increased manpower
- additional equipment
- different type of equipment
- consideration of public concerns
- different methods of protection or cleanup activities
- more direct observation and instruction to contractor or spiller
- shifting of protection or cleanup priorities

If all areas are rated as effective, he should continue monitoring and evaluating the overall spill response. If conditions do not change, he should consider termination of response effort. Procedures for determining this are given in the next section.

TABLE 32. SPILL RESPONSE EFFECTIVENESS CRITERIA

Value	Response	Source abatement	Containment at source	Sensitive areas protected	Amount of oil recovered	Areas cleaned vs. areas requiring cleaning	Manpower/equipment use	Public concerns
very effective (+3)	Within 3 hours	Stopped immediately after arrival	Contained within a small area	All sensitive areas completely protected	Most (>90%) of the oil recovered	All areas cleaned up	Perfectly suited resources: quick implementation	Considered and responded to all valid public concerns
minimally effective (0)	Within 12 hours	Stopped but after large volume of oil lost	Contained but over a large area	Most sensitive areas minimally protected	Less than half (40%) of the oil recovered	About half of the areas cleaned up	Adequate resources but some time lag	Considered but no response to public concerns
not effective (-3)	More than 24 hours	Still spilling	Not contained at source	None or few areas protected at all	Little or no (0-10%) oil recovered	No areas cleaned up	Ill-suited resources: very slow response	No consideration of public concerns

SECTION 11

TERMINATION OF EFFORT (STEP V)

It is the responsibility of the OSC to determine when recovery and clean-up efforts should be terminated. Generally, this occurs when it is apparent that additional costs (manpower, equipment, time, etc.) of continuing the cleanup effort outweigh additional benefits (aesthetic, environmental, economic, public concerns) and when certain actions have occurred, including:

- a majority of the oil has been removed from the aquatic environment
- recontamination is no longer a threat to adjacent sensitive areas
- the remaining oil is more difficult to recover because of sediment penetration or debris accumulation
- the remaining oil is either sufficiently weathered or dissipated to reduce its damage potential to a minimal level
- public pressure for cleanup has been adequately addressed, and cleanup activities are drastically interfering with the area's normal activities

If additional costs and benefits are quantified on the same scale, then deducting the costs from the benefits will determine if cleanup activities should be continued. The rating system below can be used as an input into the OSC's decision-making process.

CONTINUED EFFORT COSTS (EFFORT INDEX)

Costs of continuing the effort can be divided into five elements that, in turn, can be assigned a relative magnitude, as listed below.

<u>Criteria</u>	<u>Rating</u>	<u>Description</u>
1. Manpower requirements	+3	Increased manpower needed
- number and type of personnel needed for removal effort in area	+1	Same manpower adequate
	0	Reduced manpower sufficient

<u>Criteria</u>	<u>Rating</u>	<u>Description</u>
2. Equipment requirements	+3	Different type needed
- amount and types or removal equipment needed to clean area	+2	More of the same type
	+1	Same equipment adequate
	0	Reduced equipment sufficient
3. Time requirements	+3	Relative longer time required
- continued effort will require more or less time to recover same amount of oil per unit time	+1	Same pace adequate
	0	Relative shorter time required
4. Environmental damage	+3	Increased damage
- Further damage to ecosystem from continued intensive effort compared to no effort	+1	No change
	0	Decreased damage
	0	Decreased damage
5. Area use interference	+3	Greater interference
- further effects will hamper or cease the normal use of the area	+1	No change
	0	Less interference

By adding the ratings above (range 0 to +15) a relative magnitude of additional costs for continuing the effort can be obtained and used as the effort index.

BENEFITS FROM CONTINUED EFFORTS (BENEFIT INDEX)

The realized benefits from continued removal efforts are difficult to quantify in all situations; however, some generalized predictions can be determined if the relative value of an area's sensitivity is known. If the reason that renders an area valuable has been left intact, then removal benefits have been realized. Conversely, if the reason that makes an area valuable has not been protected or restored, no benefits have been realized. The five criteria that make up possible benefits from continued removal efforts are as follows.

<u>Criteria</u>	<u>Rating</u>	<u>Description</u>
1. Aesthetic benefits	+3	Great benefits
- preservation of visual quality and reduction of impact on scenic views	+1	Low benefits
	0	No benefits

<u>Criteria</u>	<u>Rating</u>	<u>Description</u>
2. Environmental benefits	+3	Great benefits
- protection of ocosystems and organism habitats	+1	Low benefits
	0	No benefits
3. Economic benefits	+3	Great benefits
- continuation of normal level of income from area and economic use of area	+1	Low benefits
	0	No benefits
4. Social water use benefits	+3	Great benefits
- preservation of usability of water for all purposes	.. +1	Low benefits
	0	No benefits
5. Address public pressure	+3	Great benefits
- consideration and response to public concerns and interests	+1	Low benefits
	0	No benefits

By adding the ratings above (range 0 to +15), a relative magnitude of the possible additional benefits from continuing removal efforts can be obtained. This can be defined as the benefit index.

EFFORT/BENEFIT ANALYSIS

By subtracting the effort index from the benefit index (on Table 33) a final value of -15 to +15 is obtained and is then compared to the scale presented in Table 34. The OSC can then determine if efforts should be continued or terminated or whether more information is necessary before a decision is reached.

The graph shown in Figure 12 is an aid to the OSC in this decision-making process. Additional benefits rise from initiation of the effort, reach a peak, and then decline. Additional costs increase over time commensurate with the amount of oil removed but rise sharply (beyond some point) because of the difficulty of removing the last vestiges of the spill. The ideal termination point is reached when additional benefits equal additional costs or the benefit index equals the effort index. Beyond this point, the effort is generally not effective and may damage rather than preserve the environment. Unless site-specific circumstances dictate otherwise, the OSC should terminate operations at this equality point.

TABLE 33. EFFORT/BENEFIT ANALYSIS WORKSHEET

A. EFFORT INDEX						
<u>Criteria</u>	<u>Value</u>	<u>Areas</u>				
		1	2	3	4	5
1. Manpower requirements	(0 to +3)					
2. Equipment requirements	(0 to +3)					
3. Time requirements	(0 to +3)					
4. Environmental damage	(0 to +3)					
5. Area use interference	(0 to +3)					
Total Effort Index						
B. BENEFIT INDEX						
<u>Criteria</u>	<u>Value</u>	<u>Areas</u>				
		1	2	3	4	5
1. Aesthetic benefits	(0 to +3)					
2. Environmental benefits	(0 to +3)					
3. Economic benefits	(0 to +3)					
4. Social water use benefits	(0 to +3)					
5. Address public pressure	(0 to +3)					
Total Benefit Index						
C. CALCULATION						
		<u>Areas</u>				
		1	2	3	4	5
Total Benefit Index						
minus Total Effort Index						
X =						
Compare X with values in Table 34 to determine if effort should be continued or terminated.						

TABLE 34. DETERMINATION OF REMOVAL EFFORT ACTIVITIES - CONTINUE OR TERMINATE

Value Range (x)	Action Necessary	Comments
(+3) to (+15)	Continue effort	Effort should be maintained until benefit index decreases further and/or effort index increases. Effort should be continued because additional benefits warrant additional costs.
(+3) to (-3)	Input additional* data for decision	At this point, additional data is needed to decide between continuation and termination.
(-3) to (-15)	Terminate effort	Effort should be terminated because additional benefits do not warrant additional costs.

x = benefit index - effort index

* Additional information is needed. Benefits appear marginal and may or may not warrant extra costs. These cases are completely site-specific and cannot be generalized. Data such as (1) type and duration of weather conditions, (2) possible financial restrictions, (3) area location, and (4) existence of lower priority areas all input into the OSC's decision.

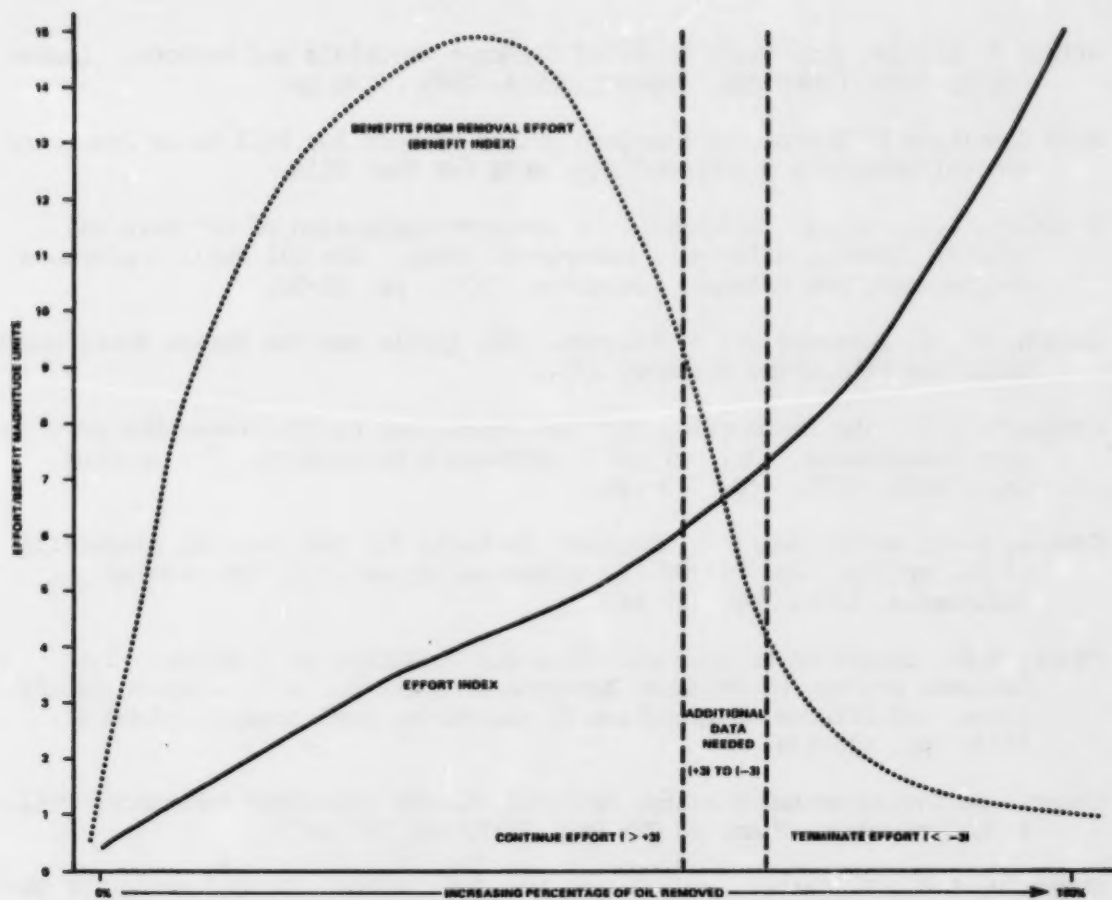


Figure 12. Benefits and effort costs vs. percent of oil removed.

BIBLIOGRAPHY

- Arthur D. Little, Inc. Guide to Water Cleanup: Materials and Methods. Learning Systems, Cambridge, Massachusetts, 1974. 335 pp.
- ASTM Committee F-20 proposed Standard Method of Test for Full Scale Advancing Removal Devices and Proposed Standards for Test Oils.
- Blaikley, D.R., et al. Slicktrak. A computer simulation of offshore oil spills, cleanup, effects of associated costs. In: Oil Spill Conference Proceedings, New Orleans, Louisiana, 1977. pp. 45-52.
- Boesch, D., C. Hershner and J. Milgram. Oil Spills and the Marine Environment. Ballinger Publishing Company, 1974.
- Canevari, G.P. The Restoration of Oiled Shorelines by the Proper Use of Chemical Dispersants. In: Oil Spill Conference Proceedings, Los Angeles, California, 1979. pp. 443-446.
- Castle, R.W., and E. Schrier. Decision Criteria for the Chemical Dispersion of Oil Spills. In: Oil Spill Conference Proceedings, Los Angeles, California, 1979. pp. 459-463.
- Clark, R.B. Impact of Chronic and Acute Oil Pollution on Seabirds. In: National Academy of Sciences Background Papers for a Workshop on Inputs, Fates, and Effects of Petroleum in the Marine Environment, Volume II, 1973. pp. 619-634.
- Council on Environmental Quality, National Oil and Hazardous Substances Pollution Contingency Plan, 40 CFR Part 1510, May 14, 1979.
- Cowardin, L.M., V. Carter, F.C. Golet, and F.T. LaRoe. Classification of Wetlands and Deepwater Habitats of the United States (an operational draft). Fish and Wildlife Service, U.S. Department of the Interior, October 1977. 100 pp.
- Cowell, E.G., G.V. Cox, and G.M. Dunnet. Applications of Ecosystem Analysis to Oil Spill Impact. In: Oil Spill Conference, Los Angeles, California, 1979. pp. 517-519.
- Der, J.J., and D.J. Graham. Quantitative Evaluation of Mechanical Oil Spill Cleanup Devices. In: Proceedings of the Joint Conference on Prevention and Control of Oil Spills, Washington, D.C., 1973. pp. 627-633.

- Edison Water Quality Laboratory, New Jersey. Oil Pollution Control Technology. National Technical Information Service (PB-258-600), 1971. 166 pp.
- Environmental Emergency Branch. Guidelines on the Use and Acceptability of Oil Spill Dispersants. Environmental Protection Service, 1-EE-73-1. Ottawa, Ontario, Canada, 1973. pp. 54.
- Environmental Emergency Branch. The Impact and Cleanup of Oil Spills on Canadian Shorelines: A Summary. Environmental Protection Service, 6-EC-78-1, Ottawa, Ontario, Canada, 1978. 25 pp.
- Fingas, M.F., W.S. Duval, and G.B. Stevenson. The Basics of Oil Spill Cleanup. Environmental Protection Service, Ottawa, Ontario, Canada, 1979. 153 pp.
- Gundlach, E.R., and M.O. Hayes. Vulnerability of Coastal Environments to Oil Spill Impacts. Marine Technology Society Journal, 12(4): 18-27, 1978.
- Henager, C.H., P.C. Walkup, J.R. Blacklau and J.P. Smith. Study of Equipment and Methods for Removing or Dispersing Oil from Open Waters. In: Proceedings of the Joint Conference on Prevention and Control of Oil Spills, Washington, D.C., 1971. pp. 405-414.
- Hess, K.W., and C.L. Kerr. A Model to Forecast the Motion of Oil on the Sea. In: Oil Spill Conference Proceedings, Los Angeles, California, 1979. pp. 653-663.
- Hum, S. The Development and Use of Resource Sensitivity Maps for Oil Spill Countermeasures. In: Oil Spill Conference Proceedings, New Orleans, Louisiana, 1977. pp. 105-110.
- Inter-Governmental Maritime Consultative Organization. Manual on Oil Pollution: Practical Information on Means of Dealing with Oil Spillages (preliminary draft). U.S. Coast Guard, Washington, D.C., 1978. 226 pp.
- Lindblom, G.P. Logistic Planning for Oil Spill Chemical Use. In: Oil Spill Conference Proceedings, Los Angeles, California, 1979. pp. 453-458.
- Lindstedt-Siva, J. Oil Spill Response Planning for Biologically Sensitive Areas. In: Oil Spill Conference Proceedings, New Orleans, Louisiana, 1977. pp. 111-114.
- Lindstedt-Siva, J. Ecological Impacts of Oil Spill Cleanup: Are They Significant? In: Oil Spill Conference Proceedings, Los Angeles, California, 1979. pp. 521-524.
- Lissauer, I.M., and J.P. Welsh. Can Oil Spill Movement Be Predicted? Symposium in the Wake of Argo Merchant. University of Rhode Island, Center for Ocean Management Studies, Kingston, Rhode Island, 1978.
- Lissauer, I.M., and D.L. Murphy. Oil Spill Forecasting - Where is it Going? In: Oil Spill Conference Proceedings, Los Angeles, California, 1979. pp. 649-651.

- Lutz, R.E., and J.P. Mech. Recovering for Marine Life Damage: Legal Aspects of Allocating Social Costs and Protecting Public Interests. In: Oil Spill Conference Proceedings, New Orleans, Louisiana, 1977. pp. 11-14.
- Mackay, D., A. Watson, N. Cecelia, and S. Nadeau. Behavior and Effectiveness of Dispersants at Sea and at Shorelines. In: Oil Spill Conference Proceedings, Los Angeles, California, 1979. pp. 447-452.
- Maiero, D.J., R.W. Castle, and O.L. Crain. Protection, Cleanup and Restoration of Salt Marshes Endangered by Oil Spills: A Procedural Manual. U.S. Environmental Protection Agency, Cincinnati, Ohio, 1978. 149 pp.
- Meade, N.F., and R.C. Anderson. Problems and Perspectives in Measuring the Social Costs of Oil Pollution. In: Oil Spill Conference Proceedings, Los Angeles, California, 1979. pp. 59-62.
- Michel, J., M.O. Hayes, and P.J. Brown. Application of an Oil Spill Vulnerability Index to the Shoreline of Lower Cook Inlet, Alaska. Environmental Geology, 2(2):107-117. 1978.
- Moore, S.F. Towards a Model of the Effects of Oil on Marine Organisms. In: National Academy of Sciences, Background Papers for a Workshop on Inputs, Fates, and Effects of Petroleum on the Marine Environment, Volume II, 1973. pp. 635-653.
- McCarthy, Jr. L.T., G.P. Lindblom, and H.F. Walter (eds). Chemical Dispersants for the Control of Oil Spills. ASTM STP 659, Philadelphia, Pennsylvania, 1978. 318 pp.
- Nadeau, J.S., and D. MacKay. Evaporation Rates of Complex Hydrocarbon Mixtures under Environmental Conditions. 1978 Spill Technology Newsletter, Environmental Protection Service, Ottawa, Ontario, Canada, Vol. 3, No. 2. pp. 41-55.
- Naval Facilities Engineering Command (NAVFAC P-908). Oil Spill Control for Inland Waters and Harbors. Department of the Navy, Alexandria, Virginia, 1977. 197 pp.
- Robertson, A.L. Selection Criteria and Laboratory Evaluation of Oil Spill Sorbents: An Update. Environmental Emergency Branch, Environmental Protection Service, Ottawa, Ontario, Canada, 1978. 78 pp.
- Schrier, E. Cleanup Efficiency and Biological Effects of a Fuel Oil Spill in Cold Weather: The 1977 Bouchard No. 65 Oil Spill in Buzzards Bay, Massachusetts. EPA-600/7-78-133, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1978. 187 pp.
- Sittig, M. Petroleum Transportation and Production: Oil Spill and Pollution Control. Noyes Data Corporation, Park Ridge, New Jersey, 1978. 360 pp.
- Stewart, R.J. The Interaction of Waves and Oil Spills. MIT Sea Grant. Report No. MITSG 75-22, Cambridge, Massachusetts, 1976. 191 pp.

- URS Research Company. Environmental Assessment and Recommendations - Barge NEPCO 140 Oil Spill - St. Lawrence River, New York. Industrial Environmental Research Laboratories, U.S. Environmental Protection Agency, Edison, New Jersey, 1976. 24 pp.
- U.S. Coast Guard. On-Scene Command. Report of Major Oil Spill - NEPCO 140 - 23 June 1976. Marine Safety Office, Buffalo, New York, 1976. 172 pp.
- U.S. Coast Guard. Merchant Marine Safety Manual, Vol. VI: Ports and Waterways Activities. Chapter 86: Emergency Response Operations. U.S. Department of Transportation, Washington, D.C.
- U.S. Environmental Protection Agency, Division of Oil and Hazardous Materials. Field Detection and Damage Assessment Manual for Oil and Hazardous Material Spills, Washington, D.C., 1972.
- Walkup, P.C., L.M. Polenti, J.D. Smith, and P.L. Peterson. Study of Equipment and Methods for Removing Oil from Harbor Waters. In: Proceedings of the Joint Conference on Prevention and Control of Oil Spills, New York, New York, 1969. pp. 237-248.
- Woodward and Clyde, Consultants. Manual of Practice for Protection and Clean-up of Ocean, Estuarine and Inland Shore lines. Industrial Environmental Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1979. pp. 245.

APPENDIX A

EXAMPLE OF USE OF MANUAL

This example of how to use the manual follows the format of the Field Manual. The hypothetical coastline spill response treated here covers a period of three days. For visual ease, Figure A-1 indicates the spill location, the coastal areas, and the resources around the spill. This is a fictitious spill and so many different area types (as stipulated) are unlikely to be found in such close proximity.

Step A. Obtain spill factors using the following methods described in Section 3.

- initial notification report
- on-site reports from disabled tanker (spiller's information)
- aerial surveillance of spill site
- private observations (local public service personnel)

Spill Factors

Time of Report: 1120, 1st day

Source: tanker

Spill Time and Date: 1030, 1st day

Location: open ocean - due west of coastline

Oil Type: viscous (fuel oil #4)

Oil Volume: 420,000 gallons (major) and still discharging at approximately 10,000 gallons per hour

Step B. Obtain environmental factors using the following methods described in Section 3.

- on-site reports from disabled tanker (spiller's information)
- aerial surveillance of spill site
- U.S. Coast Guard

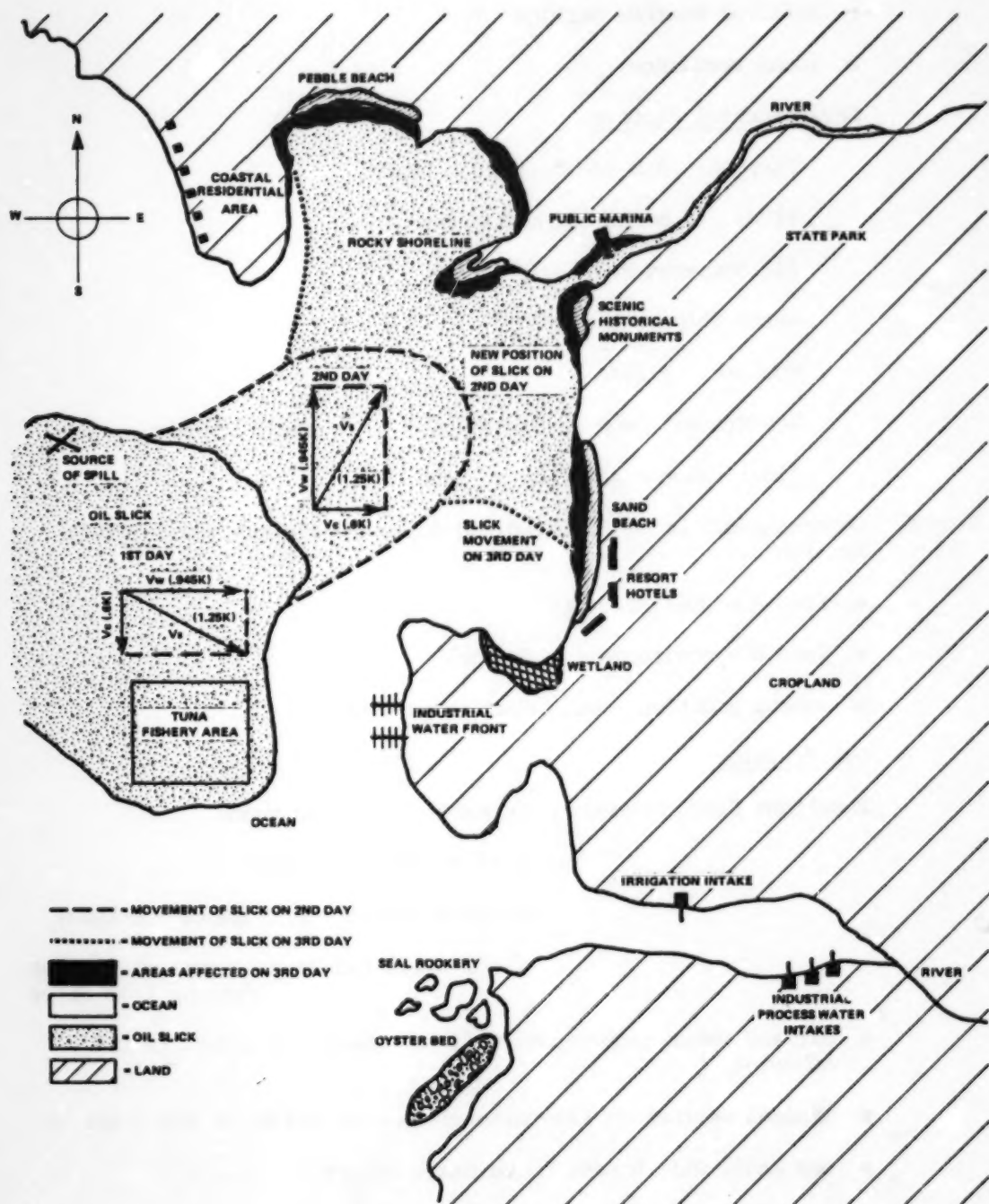


Figure A-1. Scenario: coastal spill.

- National Weather Service
- local residents

Environmental Factors

Current: 0.5 m/sec (1 knot) south

Wind: 40 km/hr (27 knots) east

Air Temperature: 30°C

Water Temperature: 20°C

Weather: clear

Sea State: high waves, 1-2.5 m (3-8 feet), no debris

Tide: high slack tide at 1000

Step C. Determine oil behavior using the following methods described in Section 3.

- Step A - spill factors
- Step B - environmental factors
- vector addition - oil behavior on water

Oil Behavior

Resultant Slick Movement: current = .6 knots south

wind = .945 knots east

slick movement = 1.25 knots southeast

final spill radius = approximately 9288
feet or 1.75 miles

- air and water temperature will not hinder or aggravate oil behavior
- minimal weathering has taken place - no effect on oil behavior
- sea state will hinder containment efforts
- weather will have no effect on operations

Step D. Determine best practical containment methods. (Section 7, Table 20)

Step E. Identify potentially sensitive areas. (Section 4)

E1. affected areas

- open waters of the ocean - tuna fisheries area

E2. threatened areas in probable order of contamination

Area A - industrial waterfront property with harbor

Area B - wetland

Area C - sand beach with resort hotels

Area D - seal rookery

Area E - oyster bed

Area F - irrigation intake

Area G - industrial process water intake

Step F. Rate sensitivity of each threatened area from Section 5 using worksheet from Section 6 (Table 10).

- Step F1 - environmental values (Section 5, Table 5)
- Step F2 - aesthetic values (Section 5, Table 6)
- Step F3 - economic values (Section 5, Table 7)
- Step F4 - social water use values (Section 5, Table 8)
- Step F5 - outside consideration values (Section 5, Table 9)
(see Worksheet for scenario)
- Step F6 - obtain modified total sensitivity rating for each area using the worksheet from Section 6, Table 11. (Steps F1 + F2 + F3 + F4 + F5) Numerical values are shown in Tables A-1 and A-2.

Step G. Rank the threatened areas according to their relative sensitivity using the worksheet from Section 6, Table 11. Numbers are in Table A-2.

Step H. Determine predicted order of contamination for threatened areas based on dynamics (Section 6).

Step I. Assign a value from the area vulnerability index from Section 6, Table 12, dependent on geomorphical components of area.

<u>Areas</u> (in predicted order of contamination)	<u>Vulnerability Index</u>
● industrial harbor	5.5
● wetland	0.5

TABLE A-1. HYPOTHETICAL COASTAL SPILL - SENSITIVITY RATING WORKSHEET
(STEPS F1, F2, F3, AND F4)

VALUES	Rating Range	SENSITIVE AREAS							
		A	B	C	D	E	F	G	H
STEP F1 ENVIRONMENTAL									
• Water Quality Degradation	0-4	1	3	2	3	3	3	4	
• Biological Productivity	0-4	0	4	2	3	3	0	0	
• Unique Habitat Uses	0-4	0	2	1	2	3	0	0	
• Ecological Vulnerability	0-4	0	4	1	4	2	0	0	
F1 Subtotal	0-20	1	13	6	12	11	3	4	
STEP F2 AESTHETIC									
• Scenic Quality	0-4	1	4	3	3	1	0	0	
• Visual Impact	0-4	1	3	4	2	1	1	0	
• Local Appreciation	0-4	1	4	4	2	1	0	0	
F2 Subtotal	0-12	3	11	11	7	3	1	0	
STEP F3 ECONOMIC									
• Income or Use Reduction	0-4	3	0	4	0	4	3	2	
• Natural Resource Damage	0-4	0	1	1	0	4	0	0	
• Replacement/Restoration Costs	0-4	3	3	3	0	3	1	1	
F3 Subtotal	0-12	6	4	8	0	11	4	3	
STEP F4 SOCIAL									
• Purpose of Use	0-4	0	0	4	0	1	1	0	
• Effect of Oil	0-4	2	0	2	0	1	3	4	
• Degree of Direct Contact	0-4	0	0	3	0	3	3	2	
• Amount of Use	0-4	1	1	1	0	3	2	2	
• Treatment Before Use	0-4	0	0	0	0	0	4	3	
F4 Subtotal	0-20	3	1	10	0	8	13	11	
TOTAL SENSITIVITY RATING	0-64	13	29	35	19	33	21	18	

TABLE A-2. HYPOTHETICAL COASTAL SPILL - AREA SENSITIVITY RANKING
(STEPS F5, F6, AND G)

VALUES	Rating Range	SENSITIVE AREAS							
		A	B	C	D	E	F	G	H
STEP F5 OUTSIDE CONSIDERATIONS									
• Political Pressure	0-4	3	3	4	3	4	1	1	
• Public Pressure	0-4	2	2	4	3	2	2	10	
• Time Restrictions	0-4	2	0	4	0	0	0	0	
F5 Subtotal	0-12	7	5	12	6	6	3	1	
TOTAL SENSITIVITY [F1-F4]	0-64	13	29	35	19	33	21	18	
STEP F6 TOTAL MODIFIED SENSITIVITY	0-76	20	34	47	25	39	24	19	
STEP G SENSITIVITY RANKING	(1-8)	6	3	1	4	2	5	7	

Areas (in predicted order of contamination)

Vulnerability Index

- sand resort beach 3.0
- seal rookery 5.5
- oyster bed 3.5
- irrigation intake 5.5
- industrial process water intake 5.5

Step J. Sum values for (1) modified sensitivity of areas (Step G), (2) predicted order of contamination (Step H), and (3) area vulnerability index (Step I), to obtain the protection priority ranking (Section 6, Table 13).

Step J (continued)

PROTECTION PRIORITY DETERMINATION

<u>Step E2</u>	<u>Step G</u>	<u>Step H</u>	<u>Step I</u>	<u>Step J</u>
<u>Identified Threatened Areas</u>	<u>Modified Area Sensitivity Rating</u>	<u>Predicted Order of Contamination</u>	<u>Area Vulnerability Index</u>	<u>Protection Priority Ranking</u>
Industrial Harbor	6	1	5.5	12.5 (fourth)
Wetland	3	2	0.5	5.5 (first)
Sand Resort Beach	1	3	3.0	7.0 (second)
Seal Rookery	4	4	5.5	13.5 (fifth)
Oyster Bed	2	5	3.5	10.5 (third)
Irrigation Intake	5	6	5.5	16.5 (sixth)
Industrial Process Water Intake	7	7	5.5	19.5 (seventh)

Step K. Determine best practical protection methods for each area from Section 8.

Step L. Implement protection actions according to priorities using best practical methods.

Step M. Reassess spill dynamics.

- shift in wind direction on 2nd day from east to north at same speed
- shift in tide-flooding upriver
- shift in current on 2nd day from south to east at same speed
- start of precipitation (rain)

Step M1. Identify additional areas threatened because of drastic change in spill dynamics (Step E2).

- scenic historical monuments
- rocky shoreline

- public marina
- pebble beach used for swimming
- coastal residential area

Step M2. Rate sensitivity of additional threatened areas using Steps F and G. In this scenario, most to least sensitive are as follows:

- public marina
- coastal residential area
- pebble beach used for swimming
- scenic historical monuments
- rocky shoreline

Step M3. Determine probable order of contamination (Step H).

Step M4. Assign area vulnerability index value (Step I).

Step M5. Determine protection priorities (Step J).

<u>Area</u>	<u>Sensitivity</u>	<u>Order of Contamination</u>	<u>Vulnerability</u>	<u>Protection Priority Ranking</u>
Public marina	1	3	4.0	8.0 (first)
Coastal residential area	2	5	5.0	12.0 (third)
Pebble beach	3	4	2.5	9.5 (second)
Historical monuments	4	1	4.5	9.5 (second)
Rocky shoreline	5	2	5.5	12.5 (fourth)

Step M6. Reorder protection priorities by combining rankings from Step J and Step M5 as follows (in order of priority ranking).

<u>Area</u>	<u>Priority Ranking</u>
● wetland	5.5
● sand resort beach	7.0
● public marina	8.0
● pebble beach	9.5*

Step M6 (continued)

<u>Area</u>	<u>Priority Ranking</u>
● historical monuments	9.5
● oyster bed	10.5
● coastal residential area	12.0
● rocky shoreline	12.5*
● industrial harbor	12.5
● seal rookery	13.5
● irrigation intake	16.5
● industrial process water intake	19.5

* When rankings are the same, the area with the highest sensitivity rating has the higher priority.

Step N. Implement actions to protect those threatened areas that have not been previously protected in Step L.

Step O. Determine areas affected by oil on 3rd day because of protective measures failure or previous contamination before protection from Section 4. In this scenario, protective measures were applied too late and these areas suffered contamination.

- pebble beach
- rocky shoreline
- public marina
- scenic historical monuments
- sand resort beach
- tuna fisheries area

Repeat

Step G. Determine sensitivity of area to oil contamination from Section 6, Table 11. (Rate the same as for protection sensitivity, but use only those areas affected.)

Step P. Determine degree of contamination for each area from Section 6 (Table 14).

<u>Area</u>	<u>Degree of Contamination</u>
Pebble beach	1
Rocky shoreline	3
Public marina	4
Scenic historical monument	1
Sand resort beach	2
Tuna fisheries area	5

Repeat Determine area vulnerability index values for each affected area
Step I. (Section 6, Table 12).

Step Q. Determine wave energy index value for each affected area (Section 6, Table 15).

<u>Area</u>	<u>Wave Energy Index</u>
Pebble beach	2
Rocky shoreline	3
Public marina	1
Scenic historical monuments	1
Sand resort beach	2
Tuna fisheries area	3

Step R. Determine cleanup priorities by summing items in Steps G, P, I, and Q using Table 16 in Section 6.

	<u>Step P</u>	<u>Step Q</u>	<u>Step R</u>	<u>Step S</u>	<u>Step T</u>
<u>Area</u>	<u>Sensitivity</u>	<u>Degree of Contamination</u>	<u>Vulnerability Index</u>	<u>Wave Energy Index</u>	<u>Cleanup Priority Ranking</u>
Pebble beach	3	1	2.0	2	8 (second)
Rocky shoreline	6	3	5.0	3	17 (fifth)
Public marina	2	4	3.5	1	10.5 (fourth)
Scenic historical monuments	4	1	4.0	1	10.0 (third)
Sand resort beach	1	2	2.5	2	7.5 (first)
Tuna fisheries area	5	5	5.5	3	18.5 (sixth)

- Step S. Determine best practical cleanup and recovery methods for each area from Sections 7 and 9.
- Step T. Implement cleanup and recovery actions on affected areas in order of priority.
- Step U. Evaluate overall spill response from Section 10 using the criteria in Table 32.

<u>Criteria</u>	<u>Rating</u>
Response time	+2
Source abatement	0
Containment at source	+1
Sensitive areas protected	0
Amount of oil recovered	+2
Areas cleaned vs. areas requiring cleaning	+3
Manpower/equipment use	+2
Public concerns	<u>+3</u>
Total Effectiveness	+13

Ineffective Spill Response Phases

- Spill should have been contained at source more effectively and rapidly (high sea conditions made this difficult).
 - More sensitive areas should have been protected (this was largely the result of drastic environmental changes on the 2nd day).
- Step V. Consider termination of effort (Section 11) in each area being cleaned up if spill response cannot address ineffective phases encountered.
- Determine continued effort costs using effort index for sand resort beach and pebble beach.

<u>Criteria</u>	<u>Sand Resort Beach</u>	<u>Pebble Beach</u>
Manpower requirements	+1	0
Equipment requirements	+3	+1
Time requirements	+3	0
Environmental damage	+3	0
Area use interference	<u>+3</u>	<u>+1</u>
Effort Index	+13	+2

- Determine benefits from continued efforts using benefit index for same two areas.

<u>Criteria</u>	<u>Sand Resort Beach</u>	<u>Pebble Beach</u>
Aesthetic benefits	0	+3
Environmental benefits	+1	+1
Economic benefits	+3	0
Social water use benefits	0	+3
Public pressure	<u>+1</u>	<u>+1</u>
Benefit Index	+5	+8

- Subtract effort index for each area from its benefit index.
 - Sand resort beach = $(+5) - (+13) = (-8)$
 - Pebble beach = $(+8) - (+2) = (+6)$
- Compare these values to Table 34 to determine if effort should be continued or terminated.
- Terminate effort on sand resort beach and continue effort on pebble beach until benefit decreases or effort increases.

APPENDIX B

COMPUTER MODELS FOR OIL SPILLS

1. SLIKTRAK. Computer simulation of offshore oil spills, cleanup, (1977 Conference) effects and associated costs.
2. A computer simulation technique for oil spills off the New Jersey-Delaware Coastline. U.S. Coast Guard Research and Development Center, Avery Point, Groton, Connecticut 06340.
3. New York Harbor Oil Drift Prediction Model, Department of Physical and Ocean Sciences. U.S. Coast Guard Academy, New London, Connecticut 06320.
4. The Use of a Diagnostic Circulation Model for Oil Trajectory Analysis. Pacific Marine Environment Laboratory, Environmental Research Laboratory, NOAA, Seattle, Washington.
5. Warner, Graham, Dean Model - Department of Navy. Basically an unsteady Ekman-type model. Major problems with moderately complex boundary conditions (shoreline, variable depth, etc.). Restricted to use in far offshore areas.
6. CEQ Model (Sewart, Devanney, Briggs, 1974). Consists of two advections models - one near shore and one offshore - need specifics on tidal current and reliable wind velocities. Major constraint in offshore use is reliability to estimate residual currents.
7. Tetra Tech Model (TT Model), Wang & Hwang (1974). Effects of local water velocities upon the spreading of the oil slick. The use is restricted to use in enclosed water bodies such as bays and harbors.
8. Seadock Model, Williams et al (1975) - probable impact of oil on shoreline and to organize a contingency cleanup program. This is the most extensive composite model; it includes three major categories (wind field, advection, and slick transformation). However, the rules of thumb used in the model in some cases are crude. Model also suffers from some inconsistencies.
9. Coast Guard Model (New York Bight) (Miller). Impact of oil spills along the N.J. and Delaware coast. Major problem when estimating velocity of oil slick movement.

10. Deepwater Ports Project Officer Model (DPPO Model) NOAA (1976). Similar to Seadock model but not as complex.
11. Delaware Model - Wang, Campbell and Ditmars (1975). Oil spills in the Delaware Bay.
12. Battelle Oil Spill Model (BOSM), Ahlstrom (1975), similar to the TT Model. Does not account for slick volume changes. The amount of oil sticking to the beach is determined by beach characteristics. However, no quantitative rules are given to determine these factors: tide, beach.
13. Narragansett Bay Model. Primack & Brown (1973), University of Rhode Island. Oil spill movement.
14. Puget Sound Model, Rath & Francis (1976), Review, and Vagners & Mar (1976).
15. San Francisco Bay Study. Conomos (1974). Correlation between oil movement and both surface and bottom drifter movement.
16. USC Model - R.L. Kolpak - funded by the API. Not yet complete (1976). The model will handle five regions to be included in a composite model: H₂O surface, H₂O columns, atmosphere, bottom sediments, and near shore zone.
17. AVCO Report, Waldman (1973). A report that may be considered as a model. Actually it is a discussion of some of the basic environmental factors influencing oil spills and methods used to model them.
18. Lower Mississippi River Simulation Model; Tsaholis, Demos, T., Shell Development Company (1979); A general riverspill simulation model to predict behavior of an oil spill.
19. Fishery - Oil Spill Interaction Model; Reed and Spaulding (1979); University of Rhode Island; Simulations of the interactive effects between an oil spill and a cod fishery on Georges Bank with impacts on commercial catch.
20. U.S. Coast Guard Oil Spill Forecasting Model, Lissauer and Murphy, U.S. Coast Guard Research and Development Center (1979). The integration of a horizontal transport model, an evaporation model, and a vertical dispersion model.
21. NWS & PU Model, Hess and Kerr, National Weather Service and Princeton University (1979) - To forecast motion of oil spilled on the surface of water.
22. Canadian Beaufort Sea Open Water Model, Venkatesh, Sahote and Rizkalla, Atmospheric Environment Service and Atmospheric Dynamic Corporation (1979). Prediction of the motion of oil spills in Canadian Arctic waters.
23. Georges Bank Model, Cornillon, Spaulding and Hansen, University of Rhode Island (1979). An oil spill treatment strategy modeling for Georges Bank.

24. FRC Model, Ta Liu and Tai Liu, Flow Research Company (1979). Laboratory experiments to investigate the effects of an oil slick on ocean waves.

APPENDIX C

OIL SPILL CLEANUP COSTS (MAY 1979 SURVEY) *

I. Labor Rates (dollars per hour)

	Straight Time		Overtime		Double Time [†]	
	range	average	range	average	range	average
Workman	\$8.00 - \$21.25	\$13.19	\$10.80 - \$34.50	\$19.94	\$13.60 - \$40.00	\$22.57
Equipment Operator	\$9.00 - \$26.00	\$15.60	\$12.15 - \$48.00	\$23.05	\$15.30 - \$52.00	\$25.29
Foreman	\$13.00 - \$30.00	\$18.08	\$16.00 - \$45.50	\$26.32	\$19.00 - \$50.00	\$28.61
Supervisor	\$15.00 - \$35.00	\$23.50	\$20.00 - \$54.50	\$30.54	\$22.50 - \$60.00	\$33.61

II. Equipment Rental Rates (cost ranges)[§]

Compressors: (based on flow capacity) Cost per day (or hour, if indicated)

85 - 200 CFM	\$42.00 - \$220.00
201 - 600 CFM	\$66.00 - \$308.00
>600 CFM	\$96.00 - \$330.00

Generators: (based on current capacity)

up to 4 KW	\$16.00 - \$60.00
5 - 15 KW	\$65.00 - \$125.00
50 - 150 KW	\$550.00 - \$750.00

Heavy-Duty Equipment: (based on size)

Backhoe	\$96.00 - \$480.00
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Front end loader	\$240.00 - \$440.00
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Tractor	\$60.00 - \$144.00
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Mobilization Equipment:

Helicopter, up to 3 hours	\$165.00 - \$310.00 per hour
more than 3 hours	\$400.00 - \$575.00 per day + \$75.00 - \$95.00 per flight hour

Plane	\$100.00 - \$320.00 per hour
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Command trailer	\$50.00 - \$100.00
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Tank storage trailer (275 - 8000 gallons)	\$7.00 - \$50.00
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4-wheel-drive truck	\$34.00 - \$160.00
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Tank storage truck (2000 - 9000 gallons)	\$160.00 - \$372.00
---	---------------------

Utility truck	\$27.50 - \$60.00
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12 - 14 ft work boat (without outboard)	\$40.00 - \$60.00
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Boston Whaler work boat (without outboard)	\$148.00 - \$300.00
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12 - 20 ft work boat (with outboard)	\$56.00 - \$240.00
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30 - 40 ft work boat (diesel-powered)	\$280.00 - \$450.00
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Work barge	\$38.00 - \$50.00
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Vacuum pumping barge	\$360.00 - \$600.00
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Pumps: (based on type and size)

Centrifugal (1 - 3 inch)	\$15.00 - \$40.00
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Single diaphragm (2-3 inch)	\$28.00 - \$50.00
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Double diaphragm (2-3 inch)	\$28.00 - \$50.00
-----------------------------	-------------------

High pressure	\$48.00 - \$75.00
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Moyno solids	\$75.00
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Submersible (1-1/2 - 8 inch)	\$24.00 - \$280.00
Dual Pass Strainer (2 - 6 inch)	\$15.00 - \$25.00
Skimmers: (based on size and capacity)	
Disc or roll type	\$100.00 - \$760.00
Single overflow Weir type	\$30.00 - \$480.00
Adjustable overflow Weir type	\$45.00 - \$480.00
Double advancing Weir type	\$400.00
Rotating porous belt type	\$96.00 - \$450.00
Support Equipment:	
Coppus air blower	\$26.50 - \$45.00
Breathing equipment	\$100.00 - \$175.00
Chemical cleaning unit	\$380.00
Communication equipment	\$20.00 - \$125.00
Boom lights	\$10.00
Flood lights	\$15.00 - \$25.00
150-watt pneumatic lights	\$12.00
500-watt mercury vapor lights	\$14.50
Sparkproof lights	\$8.00
High-pressure steam unit	\$65.00 - \$600.00
High-pressure water washer (100 psi - 10,000 psi)	\$25.00 - \$520.00
Hand dip nets	\$1.00 - \$10.00 each per day
Rakes, pitchforks, shovels	\$1.00 - \$10.00 each per day
Chain saw	\$20.00 - \$40.00
Non-sparking tools	\$100.00 - \$125.00

Vacuum Equipment: (based on storage capacity)

Vacuum truck (<2000 gallons)	\$268.00 - \$360.00
Vacuum truck (2000 - 4000 gallons)	\$280.00 - \$640.00
Vacuum truck (>4000 gallons)	\$448.00 - \$800.00
Vacuum pumping barge	\$360.00 - \$600.00

III. Materials and Supplies**

Boom rental rates (dollars per foot per day):

	1st day		2nd - 7th days		8th - 15th days		more than 15 days	
	range	average	range	average	range	average	range	average
Class I	\$.50-\$1.42	\$1.01	\$.50-\$1.35	\$.85	\$.50-\$1.35	\$.85	\$.50-\$1.35	\$.85
Class II	\$.30-\$1.50	\$.94	\$.30-\$1.25	\$.79	\$.24-\$1.25	\$.68	\$.24-\$1.25	\$.59
Class III	\$.35-\$3.00	\$1.52	\$.35-\$1.50	\$1.22	\$.25-\$1.25	\$1.01	\$.28-\$1.50	\$1.01

Boom cleaning charges \$.25 - \$1.50 per foot

Hose rental rates:

Air hose ($3/4$ - 2 inch)	\$.08 - \$.55 per foot
Fire hose (2- $1/2$ inch)	\$.20 - \$.24 per foot
Discharge hose (1- $1/2$ - 6 inch)	\$.16 - \$.76
Suction hose (3 - 6 inch)	\$.24 - \$1.00

Piston Film or Herder Chemical Costs:

Oil Herder \$13.00 per gallon

Sorbent Costs: (refer to Appendix E for sorbent efficiencies)

Particulate	\$2.92 per pound
Perlite	\$6.75 per bag
Polypropylene mop	\$35.00 each
Polyurethane	\$1.38 per cubic foot

Soda ash	\$.15 per pound
Sorbent blanket (35 inch x 200 ft)	\$96.00 each
Sorbent booms, 8" diameter	\$2.80 - \$3.88 per foot
9" diameter	\$2.90 - \$4.50 per foot
Sorbent fiber material	\$.28 - \$.40 per pound
Sorbent pads, 24 x 32 inch	\$1.00 - \$1.45 each
17-1/2 x 17-1/2 inch	\$.52 each
Sorbent pillows, 14 x 25 inch	\$7.40 - \$8.00 each
10 x 14 inch	\$2.95 each
Sorbent rolls (150 ft)	\$79.00 - \$102.00 each
Sorbent sheets, 18 x 18 inch	\$.55 each
36 x 36 inch	\$2.10 each
Sorbent sweeps (100 ft)	\$69.00 per bale
Sorbent strips (3 x 26 inch)	\$.16 each
Straw	\$5.00 per bale
Urethane foam sheets (54 x 36 inch)	\$6.00 per pound

* Costs based on representative sample of private cleanup contractors as of May 1979.

† Applicable to some companies on Sundays and holidays.

§ Daily costs based on an 8-hour work day. Cost ranges partly attributable to differences in equipment specifications. Equipment rates exclusive of operator and fuel costs.

** Refer to manufacturer's specifications for material and supplies, efficiencies and effectiveness.

APPENDIX D
COMMON CRUDE OIL PROPERTIES

Most Common Designation of Crude Stream	Producing Country	Gravity °API	Pour Point	Viscosity
Aquasay	Venezuela	38.6	N/A	N/A
Alberta Mix	Canada	38.4	- 10°F	SUS @ 100°F : 35.9
Ama	Libya	36.1	+ 75°F	Kinematic @ 37.8°C : 13.70 cSt
Anaco	Venezuela	42.4	N/A	N/A
Anquille*	Gabon	32.0	+ 3°C	N/A
Arabian heavy*	Saudi Arabia	28.2	- 30°F	70°F : 35.8 cSt Kinematic @ 100°F : 18.9 cSt
Arabian light-berri	Saudi Arabia	38.8	- 30°F	70°F : 5.65 cSt Kinematic @ 100°F : 3.78 cSt
Arabian light	Saudi Arabia	33.4	- 30°F	70°F : 10.4 cSt Kinematic @ 100°F : 6.14
Arabian medium	Saudi Arabia	30.8	+ 5°F	70°F : 16.2 Kinematic @ 100°F : 9.41
Arabian medium-Zuluf*	Saudi Arabia	30.7	- 40°F	70°F : 18.3 Kinematic @ 100°F : 10.7
Area LL-980	Venezuela	26.6	N/A	N/A
Arjuna	Indonesia, Java	37.7	+ 80°F	90°F : 39.2 SUS @ 100°F : 37.7
Arzew blend	Algeria	44.3	- 21°C	N/A
Attaka*	Indonesia, East Kalimantan	43.2	- 30°F	70°F : 1.79 cSt Kinematic @ 100°F : 1.39 cSt
Bachaquero	Venezuela	16.8	- 10°F	SUS @ 100°F : 1,362 100°F : 5.95 cSt
Bai Hassan Jambar	Iraq	34.1	- 18°C	Kinematic @ 120°F : 4.43 cSt
Barinas	Venezuela	26.6	N/A	N/A
Basrah	Iraq	33.9	+ 15°C	Kinematic @ 70°C : 32 cSt 37.8°C : 1.840 cSt
Bekapai*	Indonesia, East Kalimantan	41.1	-32.5°C	Kinematic @ 50°C : 1.540 cSt
Beryl*†	U.R.	39.5	<- 65°F	Kinematic @ 37.8°C : 2.91 cSt
Bloque	Venezuela	37.8	N/A	N/A
Bombai	Venezuela	19.6	N/A	N/A
Bonny Light	Nigeria	37.6	+ 36°F	SUS @ 100°F : 36.0
Bonny medium	Nigeria	26.0	<- 5°F	SUS @ 100°F : 60.7 100°F : 90.0
Boscan	Venezuela	10.3	+ 50°F	SUS @ 140°F : 11.18 70°F : 35.70
Brass River	Nigeria	43.0	- 5°F	SUS @ 100°C : 22.91 70°F : 5.58
Brega	Libya	40.4	+ 30°F	Kinematic @ 100°F : 3.56
Bu Attifel	Libya	40.6	+ 39°C	Kinematic @ 70°C : 3.2 cSt
Bunja	Indonesia, E. Kalimantan	32.2	+17.5°C	N/A
Buryan (Wafra)	Neutral Zone	23.3	- 5°F	Saybolt @ 122°F : 134 Pural Units
Cabinas	Venezuela	20.0	N/A	N/A
Cabinda*	Angola (Cabinda)	32.9	+ 65°F	SUS @ 100°F : 78.6
Central Lago	Venezuela	38.0	N/A	N/A
Ceuta	Venezuela	30.4	N/A	N/A
Cinta*	Indonesia, Sumatra	32.0	+ 95°F	122°F : 23.7 cSt Kinematic A 150°F : 14.2 cSt
Cretaceous	Venezuela	44.0	N/A	N/A

(continued)

APPENDIX D (CONTINUED)

Most Common Designation of Crude Stream	Producing Country	Gravity °API	Pour Point	Viscosity
Cyrus	Iran	19.0	- 10°F	SUS @ 68°F : 4,992
Darius*	Iran	33.9	0°F	68°F : 58 SUS @ 130°F : 40
Dubai	Dubai	32.5	- 5°F	Kinematic @ 70°F : 10.4 cSt 100°F : 6.35 cSt 130°F : 4.39 cSt
Duri	Indonesia, Sumatra	26.6	+ 57°F	SUS @ 100°F : 1,844
Ecuador crude (Oriente)	Ecuador	30.4	+ 20°F	SUS @ 100°F : 61.8
Ekhabinskaya	U.S.S.R.	30.7	- 17.5°F	Kinematic @ 50°C : 3.51
Ekofisk*	Norway	35.8	+ 15°F	SUS @ 100°F : 42.48
El Bundug	Abu Dhabi	38.5	- 10°C	Kinematic @ 37.8°C : 2.8 cSt
Emeraude*	Congo (Brazzaville)	23.6	- 36°C	Kinematic @ 37.8°C : 78 cSt
Ecene	Neutral Zone	18.6	- 20°F	Saybolt @ 122°F : 80.4 furnal unit
Esravos	Nigeria	36.2	+ 50°F	SUS @ 100°F : 38.2
Es Sider	Libya	37.0	- 1°C	Kinematic @ 100°F : 5.56 cSt
Fereidoon blend*	Iran	31.0	- 10°F	68°F : 94 SUS @ 130°F : 49
Forcados blend	Nigeria	30.5	+ 5°F	SUS @ 100°F : 43.6
Forbes*	U.K.	36.6	+ 30°F	SUS @ 100°F : 40.7
Fortsterton Crude	Canada	24.1	15°F	SUS @ 100°F : 139.6
Gamba	Gabon	31.8	+ 23°C	Kinematic @ 37.8°C : 36.7 cSt
Guaripa	Venezuela	avg.	N/A	N/A
Gulf of Suez blend*	Egypt	31.5	+ 40°F	68°F : 116 SUS @ 130°F : 46
Handil*	Indonesia, E. Kalimantan	30.8	+ 35°C	Kinematic @ 37.7°C : 5.872 cSt 50°C : 4.077 cSt
Hassi Messaoud	Algeria	44.0	- 24°C	Kinematic @ 14°F : 5.540 cSt 32°F : 4.112 cSt 68°F : 2.759 cSt 100°F : 1.989 cSt
Hombre Pintado	Venezuela	26.6	N/A	N/A
Hout	Neutral Zone	34.1	0°F	70°F : 10.51 cSt Kinematic @ 100°F : 6.03 cSt
Interprovincial	Canada	36.4	- 35°F	SUS @ 100°F : 41.7
Ipire	Venezuela	33.5	N/A	N/A
Iranian heavy	Iran	30.8	- 5°F	100°F : 9.81 cSt Kinematic @ 130°F : 7.55 cSt
Iranian light	Iran	33.5	- 20°F	100°F : 6.44 cSt Kinematic @ 130°F : 4.83 cSt
Jatibarang	Indonesia, Java	28.9	+110°F	122°F : 128.1 cSt Kinematic @ 140°F : 56.1 cSt
Karindingan**	Indonesia, E. Kalimantan	21.6	< 10°F	100°F : 21.9 cSt Kinematic @ 122°F : 14.4 cSt
Khafji	Neutral Zone	28.7	- 35°C	N/A
Kirkuk	Iraq	35.9	- 36°C	Kinematic @ 100°F : 4.61 cSt
Klamono	Indonesia, Irian Java	18.7	+ 40°C	Kinematic @ 50°C : 34.7 cSt
Kuwait	Kuwait	31.2	0°F	SUS @ 100°F : 58.7

(continued)

APPENDIX D (CONTINUED)

Most Common Designation of Crude Stream	Producing Country	Gravity °API	Pour Point	Viscosity
Labuan light*	Malasia, Sabah	36.0	+ 60°F	60°F : 38.4 SUS @ 100°F : 33.9
Lagomar	Venezuela	31.6		
Lagomedio	Venezuela	32.0	- 15°F	SUS @ 100°F : 55
Lagetreco	Venezuela	31.4		
Laguna	Venezuela	11.6	N/A	N/A
Lagunillas	Venezuela	15.5	N/A	N/A
Lama	Venezuela	32.6		
Lumar	Venezuela	37.0		
La Rosa	Venezuela	24.2	N/A	N/A
Leduc Woodbend	Canada	39.7	N/A	SUS @ 100°F : 39
Leona	Venezuela	24.0	N/A	N/A
Mandji blend	Gabon	29.0	N/A	SUS @ 100°F : 120
Mara	Venezuela	26.4	N/A	N/A
Mara heavy	Venezuela	17.1-avg.		
Marlago	Venezuela	27.4	N/A	N/A
Mata*	Venezuela	25.9	N/A	N/A
Malahin	Indonesia, E. Kalimantan	24.7	< 10°F	N/A
Marcades	Venezuela	29.4	N/A	N/A
Mercy	Venezuela	18.0-avg	N/A	N/A
Mesa	Venezuela	30.1	N/A	N/A
Mascla Boscan	Venezuela	32.8	N/A	N/A
Minas	Indonesia, Sumatra	35.2	+ 90°F	SUS @ 122°F : 64
Monagao heavy	Venezuela	12.0	N/A	N/A
Morichal	Venezuela	12.0	N/A	N/A
Montrose**	U.K.	41.9	+ 20°F	SUS @ 68°F : 40
Mibarras	Abu Dhabi	38.1	- 30°F	Kinematic @ 50°C : 4.7 cSt
Miraban	Abu Dhabi	39.4	- 15°F	Kinematic @ 21°C : 5.0 cSt
Ninian**	U.K.	35.1	+ 45°F	100°F : 6.94 cSt Kinematic @ 130°F : 4.66 cSt
North Slope†	USA	26.8	- 5°F	60°F : 235 SUS @ 100°F : 83
Oficina	Venezuela	36.3	N/A	N/A
Oman	Oman	34.7	- 24°C	SUS @ 100°F : 55
Oritopano	Venezuela	18.4-avg	N/A	N/A
Oscurote	Venezuela	23.2	N/A	N/A
Pacanaib	Venezuela	12.8	N/A	N/A
Pembina Crude	Canada	32.7	N/A	SUS @ 100°F : 43
Pennington*	Nigeria	37.7	+ 37°F	SUS @ 100°F : 36
Pilon	Venezuela	14.4	N/A	N/A
Piper**	U.K.	.00467 (5.6)	- 9°F	Kinematic @ 20°C : 6.97 cSt
Polang*	Indonesia, Java	43.2	+ 15°F	100°F : 1.8 cSt Kinematic @ 120°F : 1.4 cSt
Qatar Island (Dukhan)	Qatar	40.9	- 5°F	40°F : 54.6 SUS @ 80°F : 41.4
Qatar marine*	Qatar	37.0	+ 25°F	40°F : 70.6 SUS @ 80°F : 40.8
Qua Iboe*	Nigeria	37.4	+ 50°F	Kinematic @ 37.8°C : 2.89 cSt

(continued)

APPENDIX D (CONTINUED)

Most Common Designation of Crude Stream	Producing Country	Gravity °API	Pour Point	Viscosity
Quiriquire	Venezuela	16.6	N/A	N/A
Ratawi	Neutral zone	23.5	+ 15°F	Saybolt @ 122°F : 204.6 fural units
Red Water Crude	Canada	34.7	N/A	SUS @ 100°F : 46
Reforma (Cactus Reforma)	Mexico	33.0	- 5° to 10°F	Kinematic @ 100°F : 6.81 cSt
Romashkinskaya	U.S.S.R.	32.6	- 20°F	SUS @ 100°F : 50.1
Rostrum*	Iran	35.9	- 22.5°C	Kinematic @ 50°C : 3.08 cSt
Ruiz	Venezuela	31.8	N/A	N/A
San Joaquin	Venezuela	42.3	N/A	N/A
Sarit	Libya	36.5	- 5°F	Kinematic @ 37.8°C : 10.0 cSt
Sassan*	Iran	33.9	+ 15°F	SUS @ 77°F : 52.1
Seppingsan**	Indonesia, E. Kalimantan	37.9	+ 60°F	Kinematic @ 100°F : 2.18 cSt
Seria Light*	Brunei	38.8	+ 20°F	SUS @ 100°F : 1.99 cSt
Sialfjord	Norway	38.2	- 33°C	Kinematic @ 37.8°C : 33
Silvestre	Venezuela	26.4	N/A	N/A
Sirip blend	Iran	27.1	- 33°C	Kinematic @ 100°F : 4.35 cSt
Socorro	Venezuela	27.7	N/A	N/A
Sta. Rosa	Venezuela	49.8	N/A	N/A
Taching	China (PRC)	33.0	95°F	77°F : 208.9
Tasakan (Pamusian)	Indonesia, E. Kalimantan	19.5	- 45°F	SUS @ 100°F : 137.9
Temblador	Venezuela	16.9	N/A	Kinematic @ 100°F : 26.2 cSt
Tembungo*	Malaysia, Sabah	37.4	+ 25°F	N/A
Thistle**	U.K.	37.4	+ 40°F	Kinematic @ 100°F : 2.0 cSt
Tigre	Venezuela	24.5	N/A	70°F : 7.0 cSt
Tia Juana Light	Venezuela	33.4	N/A	Kinematic @ 100°F : 4.59 cSt
Tia Juana med.	Venezuela	24.9-avg	N/A	N/A
Tia Juana heavy	Venezuela	12.1	N/A	N/A
Trinidad blend	Trinidad	33.6	+ 57°F	68°F : 47
Tucupido	Venezuela	36.0	N/A	SUS @ 130°F : 38
Tyumen	U.S.S.R.	34.0	- 20°C	Kinematic @ 50°C : 3.4 cSt
Umm Shaif*	Abu Dhabi	37.6	+ 5°F	SUS @ 100°F : 38.5
Wallo Export Mix	Indonesia, W. Irian	35.4	+ 20°F	Kinematic @ 37.8°C : 4.91 cSt
Zakum*	Abu Dhabi	40.1	+ 5°F	SUS @ 100°F : 35.7
Zarzaitine*	Algeria	42.0	9°C	Kinematic @ 37.8°C : 3.4 cSt
Zweitina	Libya	39.6	+ 55°C	40°F : 202.8
				Kinematic @ 100°F : 42.2

* Wholly or partially offshore † Production not stabilized, values could change
 ‡ Field not in production. Development expected

Sources: ¹ A Guide to World Crude Oil Export Streams, Petroleum Publishing Company
 Tulsa, Oklahoma, 1976.

² Evaluation of World's Important Crudes, Petroleum Publishing Co.,
 Tulsa, Oklahoma, 1973.

APPENDIX E

MAXIMUM OIL AND WATER PICKUP BY SORBENTS*† (A.L. Robertson, 1978, modified)

SORBENT	1-Day Aged						7-Day Aged					
	g oil/g sorbent			g water/g sorbent			g oil/g sorbent			g water/g sorbent		
	CRUDE	BUNKER C	DIESEL	CRUDE	BUNKER C	DIESEL	CRUDE	BUNKER C	DIESEL	CRUDE	BUNKER C	DIESEL
<u>Organic</u>												
1. Corned (modified)	12.0	24.0	11.7	0	0	0	14.2	25.1	13.5	1.0	0	0
2. Peat Moss	4.2	3.6	3.4	0.3	0	0	3.1	3.1	2.9	0.7	0	0.1
3. Rubbermaid Black*	3.0	3.4	1.5	0	0	0.5	2.8	2.9	1.8	0.1	0	1.3
4. Silbvik	5.5	9.6	4.8	0.3	0	0	6.7	6.1	4.5	0	0	0.1
5. Straw	1.8	4.7	1.5	0	0	0.2	1.5	3.8	2.5	0.5	0	0.3
<u>Inorganic</u>												
6. Zorbite*	4.2	19.9	4.5	4.1	0	0	1.8	13.8	7.2	4.0	0	0
<u>Mixed (Organic/Inorganic)</u>												
7. Sorbent C	8.6	13.5	5.3	2.1	0	1.0	16.6	5.6	6.8	7.7	0	0.3
<u>Synthetic (Polymeric)</u>												
8. Corned Durable Pads*	20.3	23.0	17.8	1.1	0.3	0.3	15.5	22.9	18.5	4.6	0	0
9. Graboil	41.3	41.8	30.6	0	0	0	47.0	62.9	28.8	0	0	1.9
10. Rubber Pads	3.0	5.0	4.4	0	0	0	2.9	6.4	3.5	0	0	0
11. Locrat*	4.6	9.5	4.7	.02	0	0	6.4	10.1	6.0	1.3	0	0
12. Oil Sore	1.0	4.5	1.3	1.5	0	0.2	1.6	6.0	1.4	0.9	0	0
13. Ovik-Wick*	11.2	16.2	10.6	0.2	0	0.4	4.3	14.8	10.2	9.3	0	0
14. Spill Control Co. FPD*	11.6	14.5	12.6	0	0	0	10.3	14.0	10.2	0	0	0.2
15. Spill Control Co. FPD*	46.9	39.6	41.1	0	0	0	45.9	42.0	27.3	0	0	0.2
16. Taint*	11.0	14.6	9.4	0	0	0	10.1	14.7	9.0	4.0	0	0
17. 3M Fibre	11.9	12.2	10.6	0.1	0	0	12.0	9.1	10.3	0.9	0	0
18. 3M Sheet	12.4	6.7	14.7	0	0	0	13.4	10.0	13.4	0	0	0
19. Winkler Foam 50-PS-RJ*	32.4	28.0	11.3	6.0	0	0.5	31.6	42.7	14.9	2.6	0	3.0
20. Winkler Foam 50-R-PS*	13.0	10.9	3.7	3.4	0	0.5	24.3	3.8	1.5	23.8	0	1.6
21. Winkler Foam	7.0	9.4	1.6	4.0	0	0.4	21.0	8.7	2.8	14.7	0	0.2

* Sorbent not tested in the 1974 Environment Canada study.

† Based on triplicate tests.

APPENDIX F
SOURCES OF INFORMATION

Source	Information Available
U.S. EPA Regional Offices	OSC spill reports, generalized spill data, location of nearest cleanup contractors.
U.S. Coast Guard District Offices	Historical spill data, local meteorological data, oceanographic data, technical assistance for cleanup methods, locations of closest cleanup contractors.
U.S. Fish and Wildlife Service	Data pertaining to possible sensitive and unique areas, data concerning threatened species in an oil spill area, directions to take concerning the protection or cleanup of important ecological systems (rookeries, hatcheries, etc.).
State Water Departments	Data concerning all water systems within a state, some measure of outside considerations in a particular area based on experience, locations of area cleanup contractors, data concerning water uses in an area.
State Fish and Game Departments	Data detailing locations of major aquatic breeding and habitat areas within a state, data concerning wildlife water uses.
National Weather Service	Meteorological and nautical data.
Army Corps of Engineers	Historical water data for spill site, predicted flow patterns of an area.
State Coastal Department	Data on coastal shoreline development areas, data on where the recreational, commercial, and wilderness shorelines are located, data on currents, waves, and tides.
State and Local Parks and Recreation Departments	Data on the recreational use of certain areas, data on the habitats of recreational wildlife (game fishes, birds, etc.).

(continued)

APPENDIX F (CONTINUED)

Source	Information Available
USGS	Data on the geologic and hydrologic features of a spill area, topographic data, data on water uses in an area, usually in map form.
NOAA	Nautical and meteorologic data, visual reconnaissance capabilities.
State and Local Universities and Colleges	Can provide scientific data in the form of wildlife specialists, etc., can assist technically in formulating containment and cleanup efforts.
State and Local Historical and Conservation Groups	Can provide input as to the aesthetic and historical values of an area, provides information concerning local outside consideration.
National Conservation and Wildlife Organizations	Can provide input concerning the existence of threatened or endangered species in a spill area as well as providing information to determine impact on wildlife in a spill area.
State and Local Government Officials	Information concerning water uses, outside considerations, spill area uniqueness, and general information concerning logistics.